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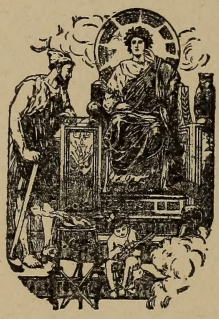

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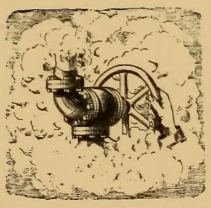

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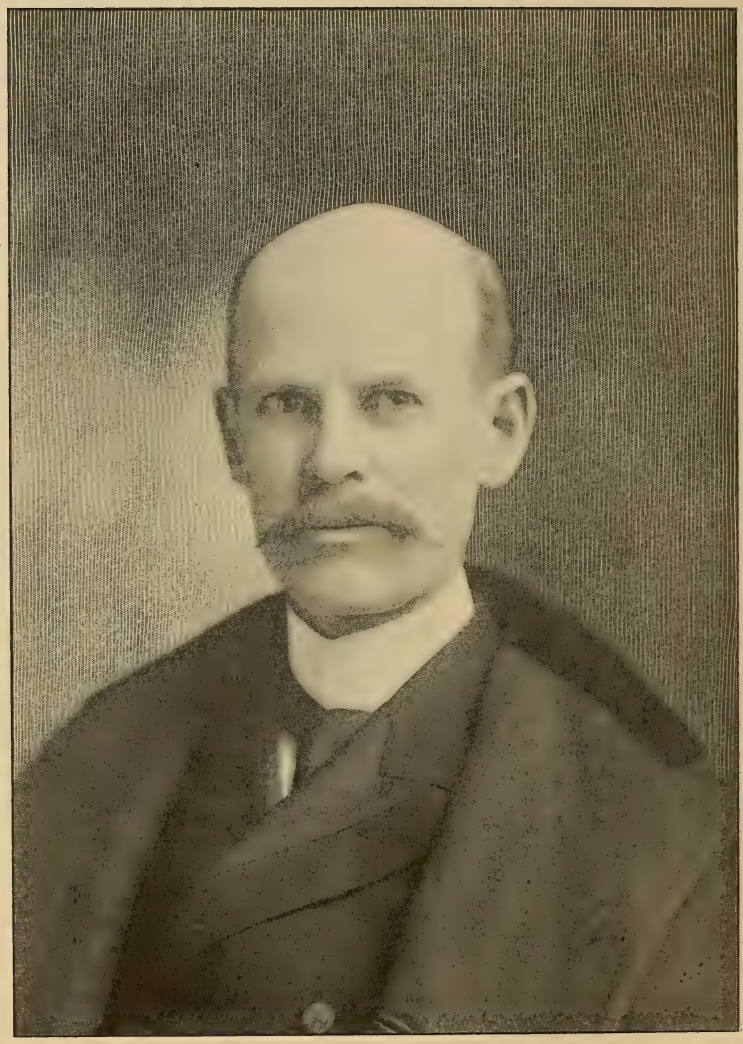

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Edward G. Acheson

THE INVENTOR OF CARBORUNDUM

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THE DEVELOPMENT OF CHINA

ENGINEERING AND INDUSTRIAL

By F. Lynwood Garrison, Mining Engineer

NATIVE TRANSPORTATION,—PEKING CART AND LITTER

SO much has been written of late about the great mineral and other resources of China that it is, perhaps, needless to dilate here upon their value and extent. While little is known of the geological condition of the various districts in which many valuable mineral deposits are found, sufficient information has been obtained in most cases to show that China contains within her boundaries incalculable riches in coal, iron, copper and other metals, not so much those called precious as the others more common and useful. In coal and iron resources China is second to no other country in the world, and if such vast stores of minerals are potentialities toward future power, China may once again become the greatest nation in Asia. The total area of the Chinese Empire is something like 4,300,000 square miles. The eighteen provinces comprising China proper, or the "Middle Kingdom," cover 1,298,000 square miles, while Manchuria has 390,000 and Thibet over 700,000 square miles. Probably but a small proportion of this vast area is totally unfit for human habitation; most of it possesses a salubrious climate similar to that of the United States.

When we hear of foreign nations, syndicates and individuals seeking, and apparently obtaining for long terms of years, exclusive mining and railway concessions to whole Chinese provinces, some of them nearly as large as France, one is staggered by the very magnitude of the grants and the extraordinary stupidity of the Chinese in making them. One syndicate alone, for example, is said to possess absolute and exclusive control for sixty years over the coal fields of Shansi and Northern Honan. These cover

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A THIBETAN FARM HOUSE

an area of over 30,000 square miles, and are probably the largest and richest coal fields in the world. In addition, this syndicate has railway franchises, or rights, that would be of the utmost value if effective. It seems probable, however, that the very size of these concessions will be their undoing. Such vast sums of money will be required to make them of use that it is very doubtful if one-hundredth part of the necessary capital can be obtained even under the most favourable circumstances.

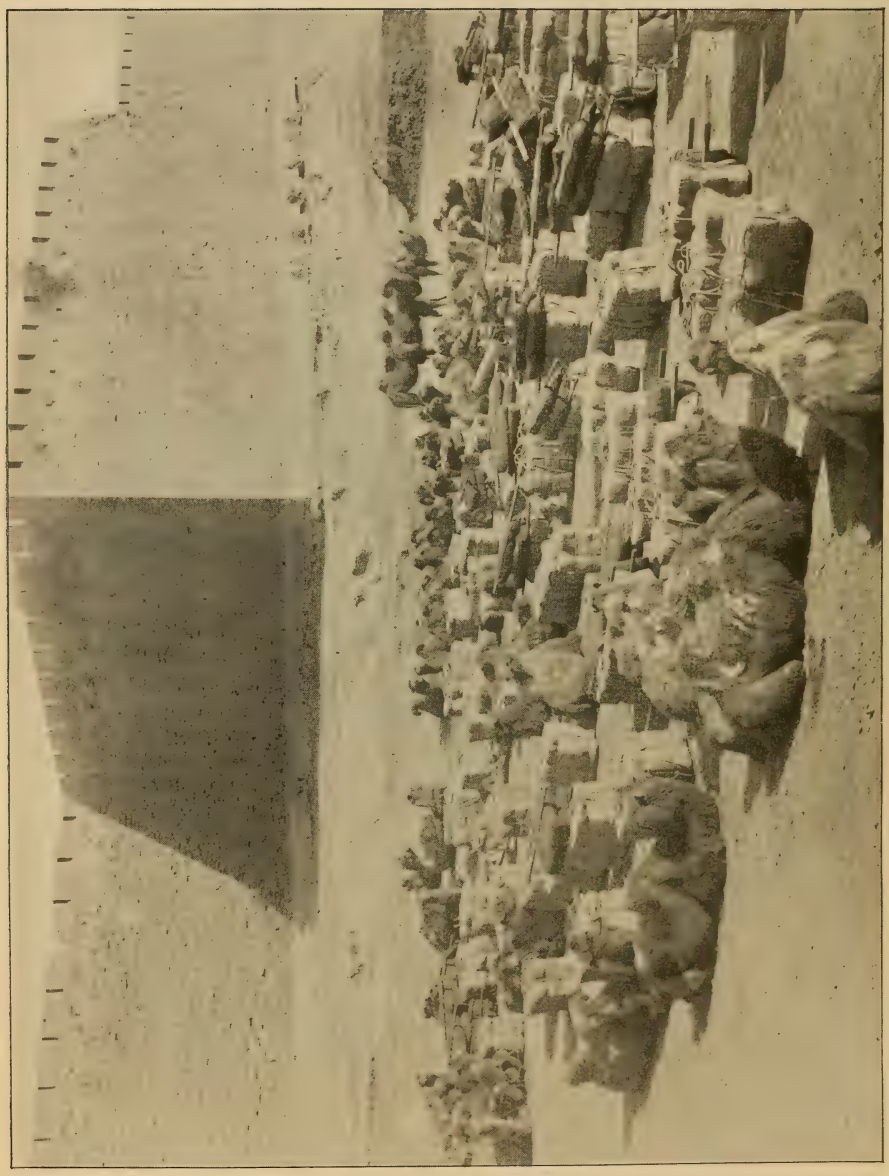
A syndicate or corporation cannot expect in a few years to open mines and create great industries in China that in other countries have been the gradual growth of a century, and then, too, what might be accomplished in a year in Europe or America may require five years or more in China. The claims of some of the loose-jointed, will-o'-the-wisp concerns that propose undertaking these gigantic development schemes are often pure humbug. Even under the ægis of the German Government in Shantung, or the flag of Russian Czar in Manchuria, it is unlikely that mining will rapidly develop into a prosperous industry. Governmental supervision and meddling are never conducive to healthy business enterprise, and are likely to be especially disastrous in China, where the people are essentially democratic and

resent official interference in their business affairs. The Chinaman is instinctively self-governing, commercial, and thrives best when left to himself. It is a great mistake to attempt to crush the Chinese spirit of independence, and if Germany, Russia or France are permitted to do it the whole world will pay dearly in the future. Syndicates and companies that propose to operate in China with the Chinamen left out of their organisation are foredoomed to failure. The Chinese have no intention of allowing their country or its riches to be exploited only for foreign benefit; they mean to have a share, and a just share, in the bounties of their native land.

Although the Chinese are well aware that they cannot themselves successfully carry on large engineering undertakings, they appear to be willing to unite with the foreigner and contribute with him on equal terms to any legitimate business enterprise that commends itself to their shrewd and practical sense. It is an error to suppose that the business and commercial classes in China are not alive to the importance or value of their natural resources. While their ignorance of science and engineering is profound, the writer found them exceeding anxious to learn anything that might become of practical account. They exhibited, for instance, the keenest desire to know the value or uses of the ores and rocks brought to him from many places in Central and Northern China.

It must not be supposed that the Chinese themselves make no attempts to mine. Usually wherever mineral deposits occur, outcropping at the surface, old pits or diggings are to be found, showing that in the past, and to a lesser degree at the present, the natives were alive to the utility and value of their mineral resources. Thus coal is mined by them wherever found above water-level, and in certain localities it has been the custom from time immemorial to wash the stream gravels for gold. In a few cases the Chinese even mine and crush the quartz capping that forms the oxidised portions of gold-bearing veins, washing out therefrom the free gold. Considerable quantities of both copper and tin are yet produced by purely native methods in Yunnan pro-

A BAMBOO POLE RAFT AT SHANGHAI



A CARAVAN RESTING OUTSIDE OF THE GATES OF PEKING

vince. In Kwei-chau province quicksilver was mined above water-level until the industry was completely destroyed by the Mohammedan rebellion fifty years ago. Such, at least, is the ostensible reason; the truth is that probably all the good ore above water-level had become exhausted.

Whenever the Chinese could mine without the necessity of handling any considerable quantity of water their operations reached a comparatively large scale. Thus, in the province of Che-kiang, at Wen-chau, there are great soapstone quarries that have been worked for hundreds of years, and from which comes the steatite so much used by the Chinese as imitation jade. The operations here are rather more than open quarries, for the work is often carried on by means of long galleries and tunnels into the hillside. Then there are the natural alum deposits, or "alum mountain," as the Chinese like to call it, between Wen-chau and San-tu-ao, in Che-kiang province. Yunnan province has been for many years noted as a copper and tin producing country; in fact, Yunnan, in a small way, seems to yield most of the common metals, besides some gold and coal. It is likely that the quicksilver industry in Kwei-chau province will soon be developed by the "Anglo-French Quicksilver Mining Concession," a new organisation with a capital of £310,000. Arsenic sulphite is also found, and, to some extent, mined, in this sparsely populated and little-known province.

The famous salt wells of Sichuen province, producing brine, oil, and gas, are worthy of special consideration, owing to the extraordinary skill and ingenuity shown by the Chinese in their methods of drilling and operating. For hundreds of years they have been using appliances which, though crude, are practically the basis from which modern methods of drilling have been developed. That depths exceeding 3000 feet have been attained by their rude bamboo apparatus attests to the wonderful patience and perseverance of the Chinese character and the cheapness of human labour in China. Some of these wells have required from twenty to thirty years in their sinking, as the only power available for the purpose is derived from coolie labour, or, at the best, that of horses and water buffaloes.

In common with the other orientals, the Chinese do not usually exhibit much inventive ability or mechanical skill. Their appliances, of all kinds, are to-day practically what they were centuries ago. Betterments do not seem to readily suggest themselves to the Chinese mind; what was good enough for their fathers is sufficient to their needs. This is the underlying principle of their religious, social, and industrial life.

The history of foreign intercourse with the Chinese does not show that they have always been opposed to foreign ideas or to more or less close social and commercial relations with Europeans. The fact that for the past three hundred years they have emigrated to all parts of the world and have been eager to trade is conclusive evidence that they realise the advantages of foreign association, at least to some extent. They do not receive new ideas with enthusiasm, but when fairly shown how their ways may be improved, they do not, apparently, hesitate to change their views.

It seems eminently proper for those who desire to participate in the industrial development of this great country to learn as much as possible of the ways and peculiarities of its remarkable people, to disabuse the mind of all preconceived notions and prejudices regarding them, and to understand at the outset that they are a highly intellectual and civilised nation. This view must not be obscured by recent barbarous events in China and popular notions regarding Chinese characteristics. They are a difficult people to understand, and the easiest way to get at the problem is to realise, in the first place, that human nature is much the same all over the world, and, in the second place, that the Chinese are a race living in the past rather than in the future. Being a free and essentially democratic people, it is highly probable that they will favour modern methods once they are made to understand their utility.

The Chinese labourer who has saved a small sum takes the first opportunity to turn to trade, exhibiting thereby his superiority of intellect, since he realises the advantages of brain over brawn. Practicality and business ability are marked traits of the Chinese character. It is of the highest importance to the success of future relations with the Chinese to clearly and fully recognise their intellectual calibre. They are good judges of men, and will demand the best other nations can send if success is to be achieved. The day is past when anybody is good enough for China, be he consul, merchant, or engineer. Great injury has been done to European and American interests in the past by an utter disregard of this fact. No people in the world require greater tact, honesty, and uprightness in their business relations than the Chinese.

Though the Chinese Government is at present weak and corrupt, it has not always been so, and it is well to realise that even now it controls more people than any other government in the world. Moreover, it has done this for a much greater length of time than any other nation, and as China, on the whole, has steadily increased in territory, population, and wealth during 4000 years of its history, it must be admitted that the Chinese have solved some political and social problems that yet vex and strain the best of modern governmental systems.

In the industrial development of China within the next decade many opportunities for speculation, if not spoliation, are likely to be offered, and the treaty ports will be thronged by a crowd of characters that are not likely to do China any good, to increase the Chinaman's respect for foreigners in general, or to reflect credit upon the countries whence they come. Such people belong to that doubtful class of foreigners that even now are so often found hanging on the skirts of rich Chinamen. Extra territoriality is the stock in trade of this individual; he investigates the treaties and finds he may do this and that; he may open mines, he may go up country, potter about and terrorise the small officials. The government is bound to give him a passport, and with that and with his consul's protection, he is afraid

GRAVES ON THE BANKS OF THE PEI HO

CARRYING BALED TEA ACROSS THE FRONTIER

of no man. If he is punished for a drunken brawl, he will complain to his consul; his word is always accepted, for he is a noble white man! If the opening up of China is to be heralded by such characters, it is not only a misfortune for the Chinese, but also is certain to be a source of endless trouble for the honest and decent foreigner who may come later.

It is but natural for the Chinese to judge foreigners by their representatives. The contrast is often painful between the single-minded, unselfish missionary and the concession-hunter above delineated. However greatly the Chinese may resent the imposition of foreign religious instruction, however much one may deplore the waste of life and effort in this respect when so much needs to be done at home, it must be admitted that the missionary, on the whole, does, and has done, a vast amount of good in China, especially when his work is associated with medical dispensation and schools for children. Far be it for the writer to join in the common, ignorant cry against the missionaries in their noble, self-sacrificing work. When the Chinese find that Western civilisation will vastly improve the comforts and well-being of the body, they may, at the same time, also discover that Christianity is equally good for the soul.

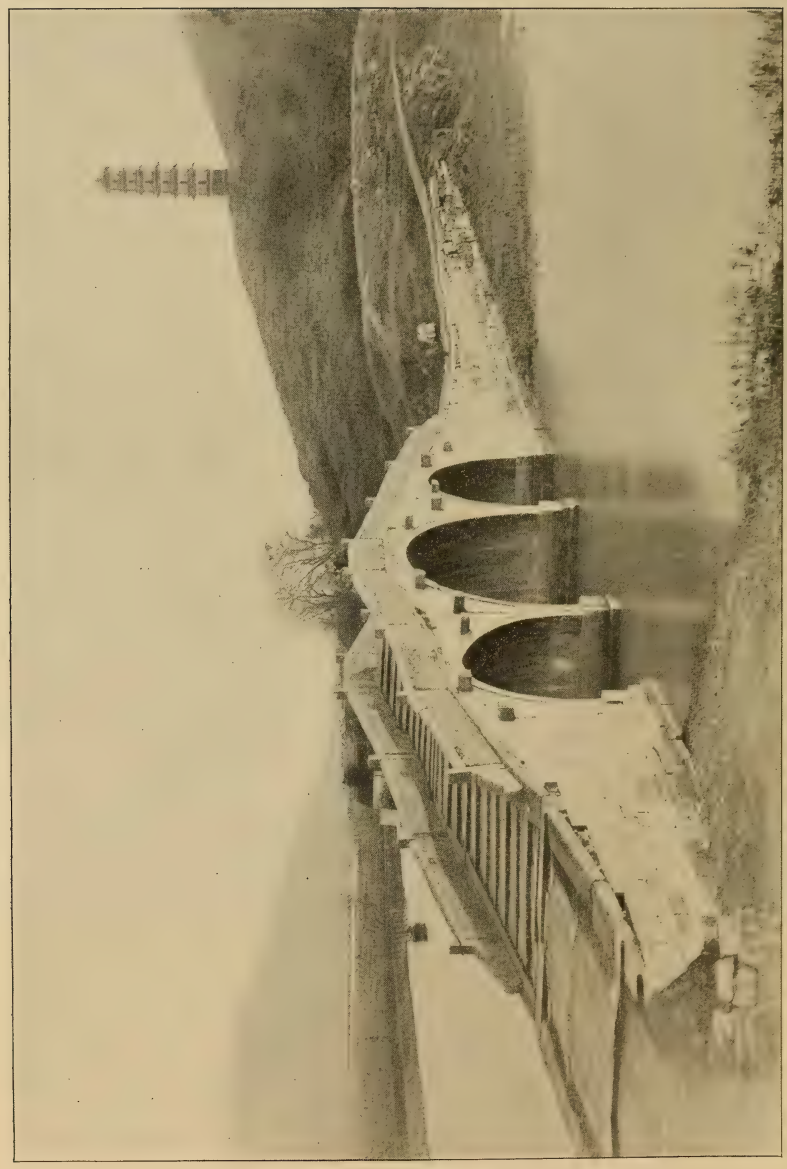
The prospective industrial development of China may, for the sake of convenience, be divided into the following general classes:—

1.—Transportation, including harbour and waterway extension and betterment.

2.—Mining and metallurgical.

3.—Manufacturing industries through which the products of the soil and mine are converted into commercial articles by modern methods.

With but slight exceptions, none of these classes of development have as yet been seriously undertaken in China. It is true that considerable railway building has been carried out in the north of China, more particularly in Chili province. The Lu-han road is being constructed to Hankow via Pao-ting-fu, and it is stated, on reliable authority, that the Germans are doing extensive work



A BRIDGE NEAR SHANGHAI

in Shantung province. The writer is not one of those who believes that unlimited and indiscriminate railway building is going to benefit China; the conditions here are quite different from those existing in America, for example, fifty or sixty years ago. It may be said that the Western States of America have been made by the railways, the tide of population flowing steadily along the paths cut by them through an uninhabited wilderness. The opening of new avenues of transportation in China, however, or the substitution of steam motive power on those already in existence, infringes at once upon thousands of native vested rights for which the treaties provide no compensation. Consequently multitudes of people will be deprived of their occupation as boatmen, muleteers, and porters, creating justifiable discontent which it will require time and great tact to allay until other vocations are found.

Then, too, the people in some sections of China are so poor and produce so little beyond their own needs that it will be exceedingly difficult to make railways, passing through such sections, self-supporting by local business. Thus, for example, take the Peking-Hankow (Lu-han) Railway! Going south from Pao-ting-fu, it passes through what is known as the "Great Plain," and will have to cross the Yellow River (Hwang-ho) near Kai-feng-fu,—an undertaking likely to be exceedingly difficult and costly. Though the road construction itself will, in some ways, be cheap, owing to the flatness of the country, expensive precautions are necessary because of the annual liability to disastrous floods when the Yellow River breaks through its banks. This, in recent years, it has always done. Hundreds of miles of country are thus inundated, producing an almost inconceivable degree of poverty among the people.

The coal fields of Hunan and Shansi, which this road is expected to tap, can be reached only by branches from the main line, unless the present plans are altered. Furthermore, Peking is not a commercial mart or centre; it is a purely governmental city, having relatively little trade. The commerce of Pao-ting-fu and Tien-Tsin will probably always continue to flow down to the sea through the Pei-ho, except during the winter months, when ice prevents navigation. The other cities and towns through which this road will pass reflect the condition of the surrounding country, which is more than likely to be deplorable.

Similar conditions do not exist in relation to the proposed railway between Hankow and Canton, passing through the rich provinces of Hunan and Kuang-tung. It is true this road will parallel the Siang River for some distance and may consequently seriously affect boat traffic on this fine stream. After leaving this river at Heng-chau, the proposed route follows the Lei branch and crosses the Nanling Mountains near the old Che-ling pass at an elevation of less than 1200 feet. According to the engineer's report, there are no grades of over one-half of one per cent. in the entire distance of 690 miles between Hankow and Canton.*

In projecting railway schemes in China it is of the greatest importance to give due consideration to the excellent existing systems of waterways that have been extensively developed in the northern and especially the central provinces. In connection with their unsurpassed river system the Chinese have covered the country with a great network of canals wherever the topography and water supply made it possible. Thus they possess a means for transport which, though slow, is exceedingly cheap and perfectly safe. Whatever may be the conditions in China fifty years hence, modern railways cannot now successfully compete with water transportation. Branch lines of railway coming down from mountainous districts to river and canal ports would, however, pay as traffic feeders to the waterways, but not otherwise. There is probably no large country in the world where water transportation can be made so easy and effective as in China. The successful application of steam-power on the Upper Yangtse River has but just

* W. B. Parsons, "Hunan, the Closed Province of China."

A RAFT ON THE UPPER YANGTSE RIVER

begun. The betterment of this and other navigable streams through use of modern engineering methods will open up to steamers thousands of miles of waterways now fit only for the Chinese sampan. The natives are unlikely to object to the improvements of their canals and rivers, whereas they are certain to throw innumerable obstacles in the path of railway construction.

A FLOATING BRIDGE IN SZE-CHUAN PROVINCE

It has often been stated the Chinese are opposed to mining from fear it would injure their *fung-shui*, or geomancy. Although this may be true in some instances, the fact remains that they have themselves been mining in a small way since, or even before, the time of Marco Polo, six or seven hundred years ago. This celebrated traveller refers to the coal dug out of the mountains near Peking and burnt instead of wood.*

While it is true that mining has been officially interdicted at certain times and places, the objections to it do not appear to have been actuated from fear of geomantic disturbances so much as from purely personal, political or business motives. It is certain that from the earliest times the Chinese have mined and smelted iron, copper, gold, silver, lead, and tin. Yunnan province now produces probably the bulk of the copper used in the interior of China. Reliable mining statistics are not to be had in China; hence any figures given out are certain to be simply the result of guesswork; but there can be no doubt that large quantities of some of the metals are obtained with the crudest and most primitive appliances.

The one large modern Chinese iron and steel plant, at Han-kow, has been a failure. Large sums of native money were here invested only to be wasted by ignorant Chinese management. There is only one modern colliery, or group of collieries, in all China, at Kaiping, several miles northeast of Tien-Tsin. This also was nearly a failure, although the yield is a good bituminous coking coal, and the district contains plenty of it. The Chinese Engineering and Mining Company, Ltd., a British enterprise, has purchased these mines, and as this corporation has a capital of £1,000,000, they will, no doubt, successfully extend the development of the Kaiping coal field and make the property pay. Legitimate corporations and investments of this kind are hopeful signs for the future prosperity of China, and it is to be regretted that there are not more of them or that there should be any lack of confidence in sensible, sound investments of this character. There are abundant opportunities to obtain them in China, and it is only necessary to treat the people in an honest, fair, and straightforward spirit.

The vast extent and value of China's unsurpassed mineral resources have been repeatedly referred to by the author. Their development will soon be commenced on a moderate scale, but it will be many years before China's iron and steel products can seriously affect the markets in other parts of the world. With coal it may be different, for there is no reason why the entire Far East and the coasts of North and South

A THIBETAN TRAVELLING MERCHANT AND HIS WIFE

* Yule's Book of Marco Polo, London, 1871, Vol. I, page 395.

America should not be supplied from this source with excellent and cheap fuel.

The vital factor in the industrial development of China and the utilisation of her resources is, of course, labour. Here it exists as in no other part of the world, unlimited, docile, and marvellously cheap. It is not cheap, however, in the same sense as the Hindu or negro labour, because it is far more vigorous and intelligent. As in other countries, the cost of labour in China is based primarily upon the supply, ability, and cost of food. In Central China it is estimated that something less than a quarter of a cent (gold) will procure enough coarse food to provide a full meal for a grown man; this, at three meals per day, would amount to $2.74 per year. No doubt this is a low estimate, but even when more than doubled, making, say, $6 per year, we obtain an idea of the remarkable manner in which the coolie class have solved the subsistence problem.

A CHINESE FARM YARD

With such a basis one can understand how it is possible to obtain such labour at wages varying from five cents as a minimum to twenty cents (gold) as a maximum per day.

It should be understood that this represents the lowest grade of labour which is unskilled. Mechanics and artisans, of course, command proportionately higher wages. On the one hand, it must not be assumed that any of this labour is as capable, man for man, as similar grades in Europe or America. On the other hand, the Chinese work longer hours, have few holidays, and do not rest Sunday or any one day of the week. Considering the quality and quantity of the Chinaman's food, it is not to be expected that he can expend on his work in a given time as much energy as the meat-fed labourer; for, other things being equal, the physical power derived from a human body is directly proportional to the food supplied. The Chinese have so successfully solved the problem of obtaining a maximum of work at a minimum cost that it is perfectly useless for a European or an American to attempt competition with him and exist.

The Chinese appear to be totally ignorant of the Malthusian doctrine, and by reason of very early marriages and a frequent legalisation of concubinage the population increases with great rapidity, so much so that the problem of the simplest existence is becoming of supreme moment in the densely populated sections of the Empire. Did China possess

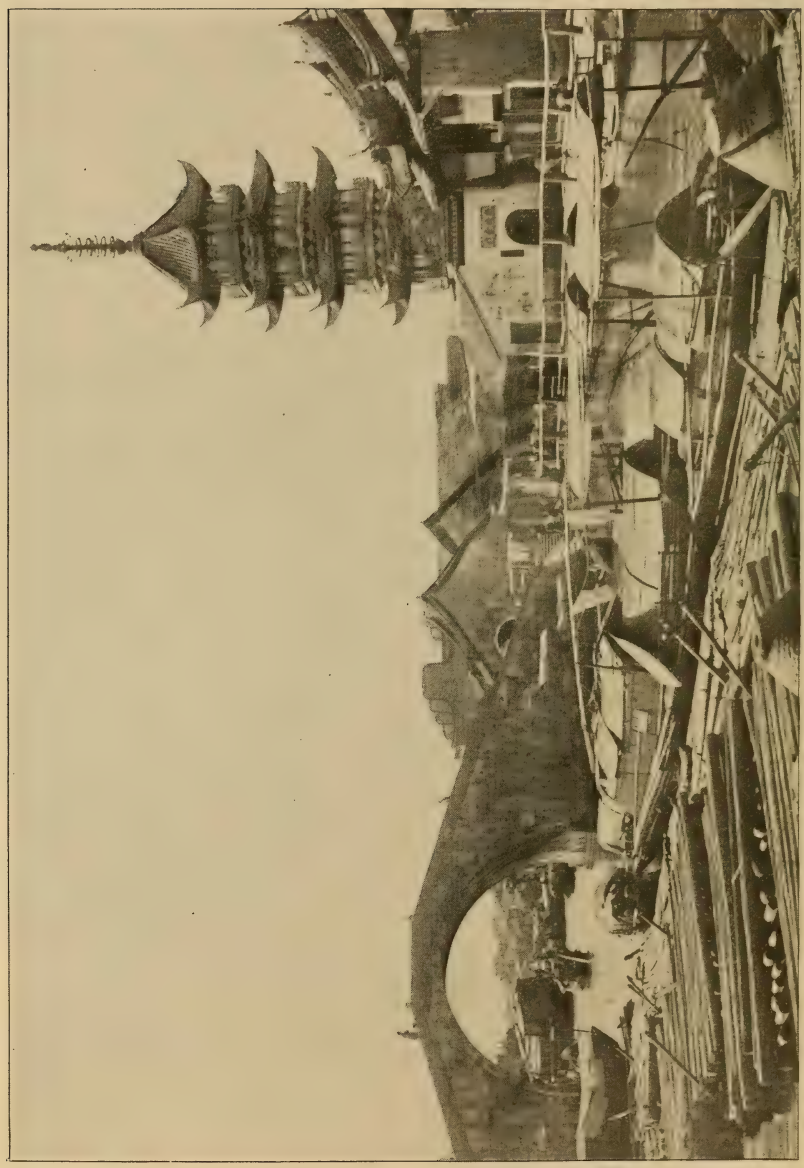
a better system of transportation, the congestion in the northern and central provinces could be relieved by emigration to the less densely populated parts of the eighteen provinces and to Manchuria, Thibet and Turkestan. It should also be remembered that at present about 95 per cent. of the population are agriculturists and live by the soil alone; mining and manufacturing industries will, in the future, provide a means of living to a great number of people now, at times, on the verge of starvation.

PLOUGHING WITH WATER BUFFALOES IN EASTERN THIBET

The development of the manufacturing industries of China will naturally first be the utilisation of their raw products and a general improvement in existing old-fashioned methods. Thus, even now, large, modern cotton and silk mills are beginning to appear in favoured places, like Shanghai. Modern systems of tea culture and treatment must also soon be established if China is to maintain its tea trade in the face of the competition of India and Ceylon.

The testimony of the best-informed authorities is wholly to the effect that the Chinese could greatly improve their agricultural and silk products by more enlightened and intelligent cultivation. For example, it is said that the tobacco grown in Sichuen province is of especially fine quality, but owing to lack of care in sorting and packing, it greatly deteriorates before reaching the market. It is not generally known outside of the Orient that the Chinese turn out little or nothing of what are commonly called dairy products,—butter, cheese, etc. The fact is that, in the Middle Kingdom at least, there are practically no grazing lands; a few goats, many pigs, and the slow, but exceedingly useful, water buffalo are the only representatives of what we call "stock."

Of course, there are horses, or rather ponies, and mules, chiefly used in transportation. The farm work, such as ploughing, is done with the buffaloes. In the north and in Mongolia the Bactrian camel is extensively used, and in Thibet the yak. In Mongolia and Thibet, where there is plenty of grass and good grazing, large herds of cattle and sheep can be raised. The natives of these favoured regions, however, appear to confine themselves to sheep and goats, the wool and hides of which are largely exported.



ALONG THE GRAND CANAL, NEAR CANTON

China has been practically denuded of timber, and, except in a few inaccessible places, little or none of value remains. Considerable quantities are said to exist in Manchuria, parts of Thibet, Turkestan, and a little in the western section of Sichuen province. Such localities are, however, so remote that this timber is unlikely to be an industrial factor for many years to come, at any rate until these places can be reached by railway. Practically all the large timber now required is imported from the northwestern coast of the United States, or from the Philippines and other East Indian islands. The natural market for the excellent timber said to exist in the Philippine Islands will be China.

China is commonly supposed to be so densely inhabited that much further increase in population cannot be supported, since the soil is now made to yield its utmost and has been so doing for perhaps hundreds of years. This hypothesis is more or less correct in some localities, and were it not for the peculiar geological formation or deposit, known to geologists under the name of "löss," that covers great areas in Kan-su, Shensi, and Chili, a great part of these provinces would have long since been added to the deserts of Mongolia.

The löss formation may be described as a fine-grained, homogeneous calcareous and sandy loam, penetrated vertically by root-like pores or tubes, which have the effect of producing vertical cleavage in the formation. When intersected by streams, this deposit readily develops into bluffs and cliffs. It usually contains land shells, and sometimes the bones of land animals; fresh water shells are rare, while marine organisms are entirely absent. In Northern China this remarkable accumulation covers vast areas and attains, in places, a thickness of from 1500 to 2000 feet. Richthofen believes this peculiar deposit to have been gradually accumulated by the winds flowing outward from the desiccated regions of Central Asia. Vast quantities of fine sand and dust are there swept up during storms and scattered far and wide over the adjoining territories, which are thus ever and anon receiving increments to their soil. Such finely sifted material is highly fertile and favours the growth of grass; every fresh deposit of dust tends to become fixed by reason of the grass, and the formation is thus gradually increased in thickness. It is this continual growth of vegetation, keeping pace, as it were, with periodical accretions of soil, that probably produces the porus capillary structure above referred to as the cause of the vertical cleavage of the "löss."

Löss occurs in many other countries, but nowhere does it attain such enormous development as in China. In Europe it is met with in the valley of the Rhine and the low ground traversed by the Danube. In America it is found in the Mississippi valley, covering quite extensive areas.

In China the löss comprises a large portion of the "Great Plain," and is somewhat developed on the Yangtse above Nanking and a little on the Han River. It spreads all over the northern provinces where it has not been eroded away. In Shensi it spreads equally over tablelands, 6000 feet high, and valleys several thousand feet less in altitude. The southern bank of the Yellow River consists entirely of löss. A peculiar feature of the formation is that it spreads alike over places which differ much in altitude, fills gaps between hills, smooths away the uneven surfaces of mountainous districts, and creates conditions for agricultural prosperity which would not exist without it. It is enormously developed in Shensi; it also spreads into Kan-su and Central Asia.

It is the löss that gives the Yellow River its colour and the Yellow Sea its name. It is supposed by some authorities that the word *hwang* (yellow) was first used as the symbol of the earth. One of the most ancient of the Chinese emperors adopted the title Hwang-ti; that is, the Lord of the Earth, or, as Richthofen translates it, "Lord of the Löss." He contends that this word could never have originated in any of the southern provinces, where the löss is absent. In de-

DRYING RICE

scribing the Wei basin, in Northern Shensi, referring to the löss, he says:—" Everything is yellow, the hills, the roads, the fields, even the waters of the rivers and brooks. * * * The houses are made of yellow earth, the vegetation is covered with yellow dust, and whatever moves on the road shares, for the same reason, the general yellow colour; even the atmosphere is seldom free from a yellow haze, due to the diffusion of the fine löss dust."

The löss is of a brownish-yellow colour, and can be rubbed between the fingers to an impalpable powder which disappears into the pores of the skin, some grains of very fine sand remaining. It is converted into a true loam by mechanical destruction, such as is caused by cart-wheels, hoofs, and feet on a high-road. It is a very productive soil, but by reason of its peculiar tubular or root-like construction, is as porous to water as a sponge; hence it needs frequent and prolonged rains. The sediments that constitute the " Great Plain " and render the Gulf of Pechili and the Yellow Sea so shallow are derived from the destruction of the löss.

The rivers which carry the löss separate it into its constituent parts, viz., sand, loam, and carbonate of lime. The latter is, of course, carried in solution into the sea, while the fine sand and loam are separately redeposited, creating in one place a poor soil and in another a deposit whose fertility exceeds that of the original löss itself. The sandy regions prevail where the rivers emerge from the mountains, while the rich alluvial loam is carried to the lower country.

It is evident that the existence of löss in Northern China makes that section distinctly different from the southern in scenery, products, and mode of agriculture. After exhaustion from prolonged cultivation this soil has the remarkable property of fertilising itself by the very simple process of spreading fresh, uncultivated earth (löss) over the land. Thus, it is credibly stated, certain valleys have been under constant cultivation for several thousand years without appreciable decrease in fertility.

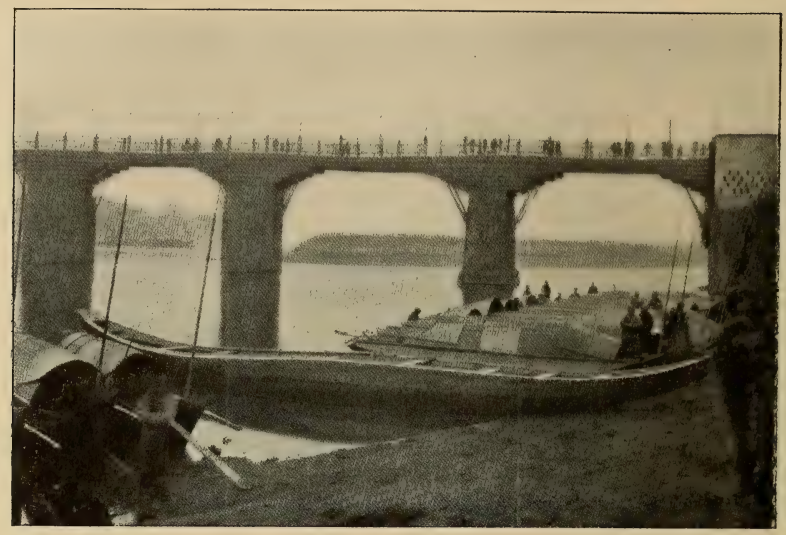
It is an indisputable fact that the Mongolian deserts are steadily creeping southward, and will continue to do so

until the skill of modern engineering checks this desiccating and deadening inroad by elaborate and expensive systems of irrigation. In some respects the Chinaman is an ideal agriculturist, and though it cannot be said that he pursues a course of fertilisation and crop regulation that would be dictated by high scientific principles, yet, within the limits of his practical knowledge and time-honoured habits, he succeeds in returning to the soil much of the nitrogenous and fertilising material that, in other countries, is absolutely wasted. Moreover, he makes every square inch under cultivation yield something of value, grudging even the tiny strips of land necessary for the narrow paths that in China serve as highways.

The absence of roads fit for waggon traffic is a very striking feature in the central and southern provinces. In the north there are some highways suitable for vehicular traffic, but they are so rough that nothing but a Peking cart can hold together when driven over them any considerable distance. As an indication of the enormous loss and detriment to the country occasioned by the almost universal absence of decent roads it has been accurately estimated that the average cost of land transport in China, whether by carts, animals, wheel barrows or men, is between 15 and 25 cents (gold) per ton per mile. Compare this with the average long-haul railway in the United States, which, is perhaps, from 0.2 cent to 2½ cents per ton-mile! Coal, costing on an average 31 cents per ton at the mines, sells for $15.30 at a point seventy-five miles distant overland; that represents a charge of about 20 cents per ton-mile, which seems to be the common overland freight rate in China.

There are some sinologues who are disposed to maintain that the Chinese, in one way or another, have anticipated most of our important modern inventions. While this is certainly not true, there can be no doubt that for many hundreds of years they have been familiar with a few of the arts and sciences that we are disposed to regard as purely modern. Some of the ancient Chinese work of engineering character shows that they possessed a high degree of skill at an early stage in their history. Take, for example, the stone arch bridges found here and there through-

THE CHINESE IDEA OF A SAW MILL



A WOODEN CANTILEVER BRIDGE OVER THE LU HO

out China; some of these arches are very old, and all of them exhibit a symmetry and gracefulness obtainable only with a high degree of skill. Then, too, the cantilever principle of bridge construction has long been known to China. In the illustration above we have an excellent type of this kind, which is described by Parsons* as follows:—

"This bridge consisted of six spans, with a length of 480 feet and width of 20 feet, paved with cobblestones, while over it is erected a frame to carry awning mats in summer. The substructure is masonry piers, in good condition, but evidently of great age, while the superstructure is of wood and a genuine cantilever in design. The timbers which compose it are about 10 inches square, laid in alternate layers in the direction of, and across, the line of the bridge. As will be seen from the illustration, each longitudinal layer projects beyond the next one below, and the series of such projections builds out the cantilever arms until the opposite ones are near enough together to be spanned by a single timber. The superstructure is not so old as the substructure, the timber having been undoubtedly replaced, possibly many times."

Suspension bridges are common in the mountainous districts of the provinces of Sichuen and Yuannan. They are made of wrought-iron bars linked together, as shown in the illustration on page 12. They are sometimes as much as 250 feet or more in length by about 10 to 12 feet in width, and nearly always exhibit a remarkable degree of strength and delicacy of design.

The "Grand Canal," extending from Hang-chau on the south to Peking on the north, a distance of over 700 miles, is, perhaps, the greatest practical engineering feat ever undertaken by the Chinese. As it was never provided with locks, has been neglected, and consequently is in bad repair, its glory as an artificial waterway has long since departed. But between Chin-kiang, on the Yangtse River, and Hang-chau at tide-water, it is still in fairly good condition, and is the avenue for the enormous traffic between those two ports. The construction of the Grand Canal was the work of the Mongol Emperor Kublai Khan, who reigned about 600 years ago.

The "Great Wall" may also be considered an important engineering under-

* An American Engineer in China. William Barclay Parsons. Published by McClure, Phillips & Co., New York.

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taking by reason of its vast size. Its construction was begun in the Tsin dynasty about 220 B. C., but was not entirely completed until the time of the Mings, in the early part of the sixteenth century. This work is remarkable more as a monument of brutal human industry than as a useful, practical piece of engineering, resembling in this respect the Pyramids of Egypt. It is true this wall served at times the purpose for which it was designed,—as a bulwark against the Mongolian hordes,—but probably at the expense of the valour and watchfulness of the Chinese.

In the diking of the Yellow River, the Chinese in the past have exhibited considerable engineering skill; now, however, this important work receives little or no attention, with consequent disastrous results to the surrounding country from repeated inundations.

Reference has already been made to the ingenious methods in vogue with the drilling of wells for brine and gas in the Tsz-lin-tsing district of Sichuen province. Other instances might be given wherein the Chinese show remarkable sagacity and no small degree of mechanical skill; hence, it must be evident to those who have come in contact with them that they are just as capable of adapting themselves to modern conditions and in using improved machinery as their kinsmen, the Japanese.

In the metallurgical arts the Chinese show decided evidences of stagnation, not to say retrogression. Thus, they were once expert in producing both wrought and cast iron. The making of iron castings of considerable size being a very unusual accomplishment among primitive people, they must have had, in the past, better knowledge of metallurgy than at present. Copper, lead, and silver the Chinese still produce from their ores, and gold they wash from the river gravels.

They also have methods of assaying silver bullion, which, while not accurate according to our present ideas, show considerable ingenuity.

According to Percy, it is probable that the Chinese produced zinc long before Europeans. That is, they produced the metal itself and did not make their brass by a simple admixture of copper with the mineral calamine, as did the ancient Romans. To those familiar with the metallurgy of zinc this is evidently a remarkable circumstance. Percy also states that they were not acquainted with the art of rolling brass, and, as a substitute, cast it into tolerably thin sheets, slightly exceeding one-sixteenth of an inch in thickness. At present almost every art and science in China is either stagnant or decadent. It would seem, therefore, that the time for a renaissance is at hand.

THE "HANDY" MEN OF THE RAILWAY

A STUDY OF BRITISH TANK LOCOMOTIVES

By J. F. Gairns

RAILWAY express engines have always received attention, both at the hands of writers on railway subjects and in the eyes of observers, technical and otherwise; but tank engines and goods engines are counted as of little consequence by the majority of observers and writers, and it is with the former of these engines that the writer will, therefore, deal in the following pages.

Probably no more expressive name could be applied to these tank engines than that chosen in the title of this article, for they are, in truth, "handy" men, suitable, often irrespective of type, for working local, slow main-line, short-distance express, and goods traffic. They have driving wheels of moderate dimensions, usually four-coupled for passenger working, though there are now many six-coupled engines designed expressly for hauling passenger trains, and also for goods traffic and shunting. Consequently they are capable of "starting away" readily with heavy trains; they get into speed quickly, and are thus eminently suitable for short, between-station runs. The passenger tank engines in use are sufficiently powerful to take the place of goods engines on most trains; they are capable of good and fairly high speeds, and can work many fast trains efficiently, provided the runs are not too long; they occupy less siding space than a tender engine, and, of course, cost less; and they are, as a rule, equally efficient when run either chimney or bunker first.

The earliest tank engines, like the tender engines, were single-driving for passenger work and four-coupled for

FIG. I.—A SIX-WHEELER, FOUR-COUPLED IN-FRONT TYPE, ON THE LONDON, BRIGHTON & SOUTH COAST RAILWAY

FROM A PHOTOGRAPH BY A. J. CHISHOLM

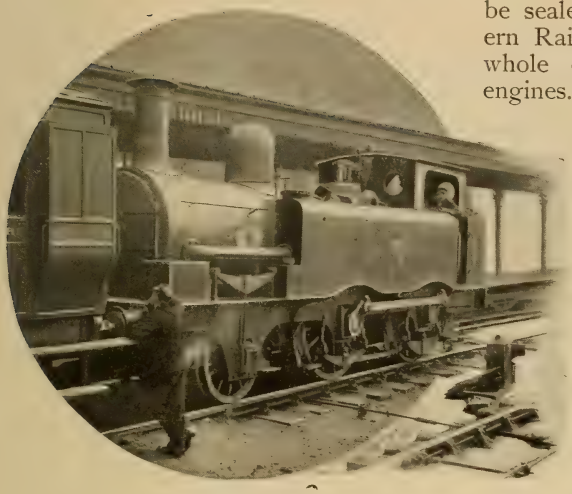


FIG. 2.—A SIX-WHEELED FOUR-COUPLED-BEHIND ENGINE

PHOTO BY G. J. PRENTICE

goods work, but the single-driving type became practically extinct long ago. In the case of tender engines that result has not yet been attained, but experience seems to indicate that it is not far distant. Four-coupled engines have been the standard for the last fifty years, though it is now not unusual to find six-coupled engines employed and designed for passenger work. Six-coupled engines have been the rule for goods and shunting work. A few "single" tank engines are to be found on the Isle of Wight and some of the Irish railways, and on light railways such as the Clevedon & Portishead Railway; but on the main lines the sole remaining representatives of the type are provided by the inspection engines.

The next type followed the lines of tender engine development, and was six-wheeled, with the driving and trailing wheels coupled. Bunker and well tanks were employed; later side tanks became general. This type now has only one real supporter, and even there its doom appears to be sealed. This is on the Great Western Railway, which works almost the whole of its local trains with these engines. Fig. 3 shows one of them. It is fitted with condensing apparatus for working on the London Underground Railways, and practically the only difference between London and provincial engines consists in the fitting, or not, of condensing apparatus. The design is nearly thirty years old, and has been very little altered in later builds, though some of the engines are of comparatively recent date. With their 5-foot wheels and 16 × 22-inch-cylinders they are set to do some remarkable work. Many of the Paddington - Windsor and Paddington-High Wycombe express trains are worked by them, at averages of forty-five miles an hour and over, for distances of eighteen and twenty-four miles, respectively, with by no means light loads, though the road is an easy one. It is a pity that proper cabs are not fitted to more than a few of them.

Fig. 2 shows a London, Chatham & Dover engine of the same type, but having outside bearings to the coupled wheels. These are old engines, but, with their 5-foot 6-inch wheels, have a

FIG. 3.—GREAT WESTERN RAILWAY STANDARD TANK ENGINE, SIX-WHEEL, FOUR-COUPLED-BEHIND TYPE

PHOTO BY A. J. CHISHOLM

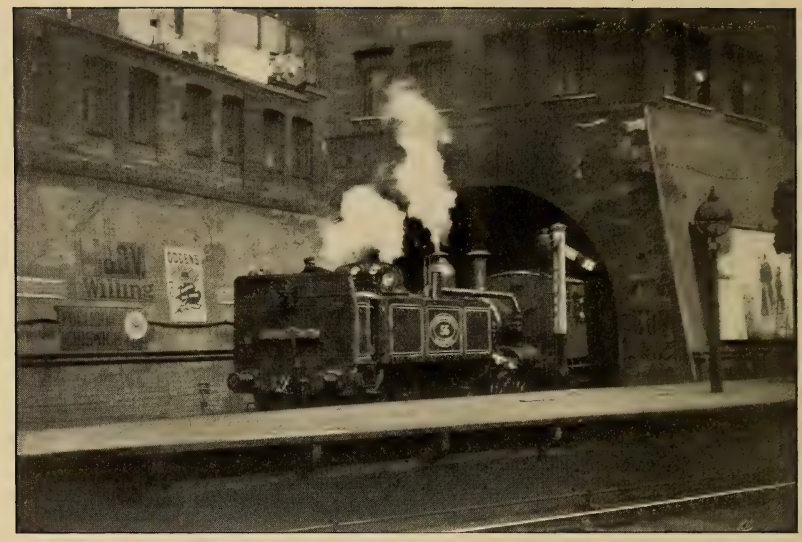


FIG. 5.—ON THE METROPOLITAN RAILWAY. AT THE MOUTH OF THE ALDGATE TUNNEL

PHOTO BY A. J. CHISHOLM

FIG. 4.—METROPOLITAN RAILWAY ENGINE IN OLD CONDITION. LEADING BOGIE FOUR-COUPLED-BEHIND TYPE

PHOTO BY O. C. OWENS

good reputation for speediness, as, indeed, have all the tank engines of the much-maligned Chatham & Dover, whatever may be the case with the tender engines of that line. The Metropolitan Railway also have a few engines of the type, used principally for goods traffic; otherwise, there are only a few isolated examples finishing their days on branch lines.

The London & North-Western Railway did have a large number of such engines, some with 4-foot 6-inch and some with 5-foot 6-inch wheels; but all of these, or nearly all, have had their frames lengthened, a larger bunker fitted, and a pair of trailing wheels added.

Almost concurrently with the type just mentioned appeared another six-wheeled type, this time having the leading and driving wheels coupled; and this, until the demand for more power imperatively called for larger engines, has been the favourite design for passenger tank engines. Fig. 1 shows "Pelham," one of the late Mr. Stroudley's famous and numerous "D Class" engines, for the London, Brighton & South Coast Railway. And splendid work these engines have done, and do still, though superseded now to some extent by other designs. There is an appearance of fragility about them; they are almost beautiful, when kept clean and bright, which is not usually the case now, and alongside other companies' engines they seem very small and delicate. Yet they have a reputation for speed and for good all-round work. They are not likely to disappear from London for a long time yet.

The next development consisted in replacing the single carrying axle in both of the six-wheeled types described by a four-wheeled bogie, necessitated by the increase in weight and the enlargement of the bunker to carry more coal and water. Thus we get, in the one case, leading-bogie-four-coupled-behind engines, and in the other, four-coupled-in-front-trailing-bogie engines. The first of these has only four real supporters, only two of which now build such engines. These are the North London, North British, Metropolitan and Metropolitan District, or "District," railways. The North London consider this their standard type, and it has been for many years. The cylinders, as in the case of the Metropolitan and District Railway engines, are outside. The North London also possess two classes of older engines of the type, the cylinders of which are inside, one class having 5-foot 4-inch wheels, and the other,—long renowned for speed capabilities,—6-foot wheels.

FIG. 6.—A TRAILING-BOGIE, FOUR-COUPLED IN FRONT TYPE ON THE SOUTH EASTERN RAILWAY

PHOTO BY G. J. PRENTICE

The North British engines are very numerous, and the type is, the writer believes, still the standard. In this case the cylinders are placed inside.

The Metropolitan and District engines are near relatives, being indeed built to the same design, though dressed differently. The design was introduced by Sir John Fowler expressly to suit underground requirements, and although all the engines are rather old, the whole of the underground traffic on both lines is worked by them, though on the Metropolitan St. John's Wood line they have

FIG. 7.—A TRAILING-BOGIE FOUR-COUPLED-IN-FRONT TYPE ON THE LONDON & SOUTH WESTERN RAILWAY

PHOTO BY G. J. PRENTICE

now been ousted on the best trains by new engines of other types.

The District has not purchased any new engines for many years, but as they have only the one type, it is probable that, when necessary, it will be continued.

Fig. 4 shows a Metropolitan engine in the condition of twelve years or so ago. Fig. 5 shows one on a New-Cross-Hammersmith train emerging from the Aldgate East Tunnel, alongside Aldgate main station, in one of the various present-day dresses.

As stated previously, the coupled-in-front-six-wheeled type has been in great favour, and its development with a trailing bogie has been as much so. It is at the present day by far the most numerous class of engine, except the ordinary six-coupled goods engine, and there are only two of the "Great" railways which have nothing to do with it,—the London & North-Western and the Great Central.

Fig. 6 illustrates one of Mr. Stirling's domeless engines for the South-Eastern Railway, and Fig. 7 one of Mr. D. Drummond's big tank engines for the London & South-Western Railway. Both of these classes have good characters for speed and work.

The Great Eastern Railway is a very important stronghold of the type. There are old engines of several classes with 4-foot 10-inch wheels, which, nevertheless, do splendid work still on the heavy London suburban traffic; some still older ones, with 5-foot 3-inch wheels,

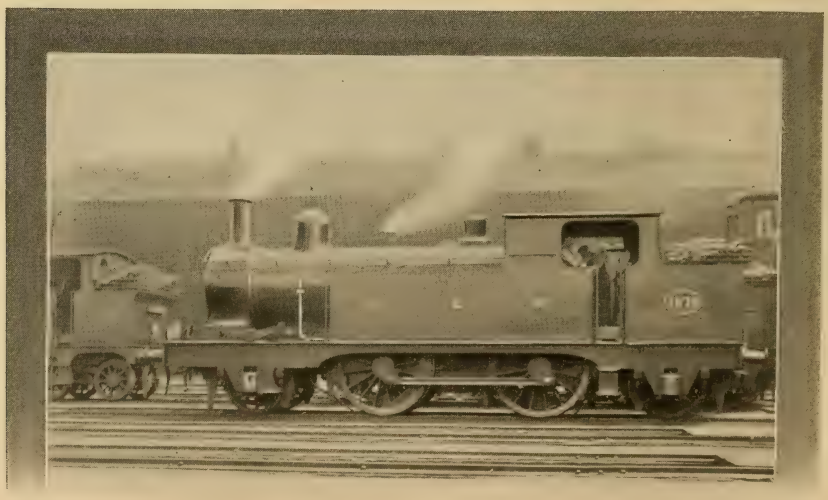


FIG. 8.—A MAIN LINE ENGINE ON THE GREAT EASTERN RAILWAY, A "DOUBLE-ENDER

PHOTO BY G. J. PRENTICE

now relegated to country districts; and Mr. Holden's newly introduced, but already numerous, 1100 class, with 4-foot 11-inch wheels.

The Midland, South-Eastern & Chatham (both South-Eastern & Chatham and Dover sections), North-Eastern, London & South-Western, Caledonian, Glasgow & South-Western and numerous smaller lines now build no other class. The Great Northern, after making it their standard for many years, has only recently discontinued it in favour of ten-wheeled engines. The Great Western not so many years ago had a good number of these engines, but, for some reason or other, most, if not all, have been "converted," in a manner not very clear, to mixed-traffic tender engines. The Metropolitan, Lancashire & Yorkshire, North British and a few other railways also possess engines of the type. In fact, with the exceptions already noted, these engines are to be found almost everywhere.

The next development to be considered, and one which in some cases preceded that just dealt with, produced the eight-wheeler, "double-ender" type, of which two specimens are shown, one (Fig. 8) a Great Eastern main line or "big" double-ender, and the other (Fig. 9) a London & North-Western engine of a similar class. Mr. Worsdell introduced the type on the Great Eastern in 1884, his engines, thirty in number, being known as small "double-enders." Mr. Holden built ten more of the same class, and in 1893 introduced the big "double-enders," of which Fig. 8 shows one for main line and short-distance express work. There are forty of each of the classes, and the smaller ones have 5-foot 3-inch wheels, while the larger ones have 5-foot 8-inch wheels. When Mr. Worsdell went to the North-Eastern locomotive headquarters at Gateshead he brought out a class of double-ender tank engine very similar to his Great Eastern engines, and, rather curiously, several of these engines bear the same numbers as their relatives on the Great Eastern.

FIG. 9.—ONE OF THE LONDON & NORTH WESTERN ENGINES

PHOTO BY J. LAKE

The London & North-Western has long been famous for its double-enders. There are two classes, one with 4-foot 6-inch wheels and the other with 5-foot 6-inch wheels, and all of them are noted for good work. The 5-foot 6-inch engines are very speedy. The writer has

FIG. 10.—A TEN-WHEELER ON THE LONDON & SOUTH WESTERN RAILWAY

PHOTO BY G. J. PRENTICE

timed them with good loads, 15½ minutes for 12½ miles, start to stop, and actual speeds of 64 miles per hour have been recorded for them, and also for the big Great Eastern double-enders.

The Lancashire & Yorkshire and the Great Central railways are also very fond of double-enders, using 5 feet 8 inches as wheel diameter; but, together with the London & North-Western, are now introducing extensively for passenger work eight-wheeled, six-coupled engines.

At first sight, it appears as if the double-ender type should be the most suitable design for a tank engine; but it does not seem to be borne out in practice, for there is no railway, with the doubtful exception of the Lancashire & Yorkshire and the Great Central, besides the Great Western, with its one engine, which now builds them. The Great Eastern and the North-Eastern have reverted to trailing-bogie tanks, and the other lines to six-coupled engines, as already mentioned. Scotland, to the best of the writer's knowledge, does not possess a single double-ender tank engine.

Just as big engines have become the order of the day for express work, heavy tank engines of large dimensions have appeared in several quarters, having more than eight wheels. Of the four-coupled classes the most noteworthy are those on the London & South-Western, the London, Tilbury & Southend, the Great Northern, and the Taff Vale railways. Fig. 10 illustrates one of the ten-wheelers for the first-mentioned railway. These engines, which are often termed "Windsor bogies," are now rather old, but they still work most of the fast trains on the Windsor, Staines & Reading lines, besides taking their part on local work.

The London, Tilbury & Southend Railway is the principal line for these ten-wheelers, for out of a total locomotive stock of sixty-two engines, sixty are of this type. Of these, thirty-six have only 6-foot wheels, and, although considered as the smaller engines, are yet very big machines, weighing, in working order, fifty-five tons. Many of these are now confined to goods work. The remaining twenty-four engines are much bigger, and, although of three different builds, and really of two classes, all have 6-foot 6-inch wheels, the largest ever used for a modern tank engine. Fig. 11 shows one of the latest of these en-

gines. They are intended for working the fast Southend trains at high speeds and with good loads; but they are very efficient also with the heavy local trains, despite their big wheels, and it must be remembered that a "Tilbury Workmen's Train" is not to be despised,—twenty-two coaches, some of them six-wheeled, all "packed" in the fullest meaning of the word. It must be seen to be appreciated.

The Great Northern engines, introduced by Mr. Ivatt a few years ago, have the cylinders inside, but otherwise they are very similar in general appearance to the Tilbury engines, though only equal in size to the 6-foot engines of the Southend Company. The Great Northern engines have 5-foot 6-inch driving wheels; but there are two classes of them, one intended for London work, and the other, and older, for country and provincial lines.

The Taff Vale Railway is also a prominent user of these ten-wheelers,—cylinders inside. Of other railways, there are the London & North-Western, with the old converted Metropolitan engines, already referred to, and several of the Irish lines. Those on the Belfast & Northern Counties Railway are two-cylinder compounds.

Ten wheels might be deemed sufficient to carry even the largest tank engine, but on two railways still another pair of wheels has been employed. The Wirral and the Somerset & Dorset railways have each one or two double-bogie tank engines; that is, engines with a four-wheel bogie at each end, and four-coupled wheels, making them practically "bogie double-enders" having twelve wheels. These engines are few in number as yet, and it does not seem likely that they will be multiplied to any extent for a few years, but the type is undoubtedly one of the future.

And now for a brief consideration of the six-coupled tank engines. The writer may dismiss here, without comment, the ordinary six-wheeled, all-coupled tank engine used for goods and shunting work. For passenger work, however, the type is rather unusual, only two railways classing such engines as passenger engines, though all railways have some fitted with a continuous brake, so as to be able to work passenger trains, if necessary, and occasionally.

Mr. Stroudley, on the London,

FIG. II.—EXPRESS TANK ENGINE, TEN-WHEEL TYPE, ON THE LONDON, TILBURY & SOUTHEND RAILWAY.

FROM A PHOTOGRAPH BY G. J. PRENTICE

Brighton & South Coast Railway, was responsible for the first six-coupled design for passenger tank engines, and his "Terriers" (see Fig. 12) are world-famous, though their day is almost over. Tiny engines, wheels only 3 feet 10 inches in diameter, chimneys hardly reaching to the carriage roof level, although rather long,—for them no more appropriate nickname could have been found than that of "Terriers," for they verily "worry" a train from a station as a terrier worries a rat. Many of them have been sold to light railways, but they are still numerous in and around London. They do their share of work on the South London and East London lines, and are very useful as shunters at London Bridge and Victoria.

The other early user of six-coupled passenger engines is the Great Eastern Railway. Here there are more than a hundred, and they do good work with the heavy Enfield, Edmonton and Clungford trains, and although their wheels are only 4 feet in diameter, they engines have had the front halves of the coupling rods removed.

The more strictly passenger type of six-coupled engine is, however, that known as the "six-coupled radial," that is, having a trailing axle fitted with radial axle-boxes, in addition to the coupled wheels. These are now standard engines on the London & North-Western; London, Brighton & South Coast; Lancashire & Yorkshire; and Great Central railways, while they have also been introduced on the Taff Vale and Wirral railways, and for goods traffic on the North-Eastern Railway, not to mention other and smaller railways.

One of the London & North-Western engines is shown in Fig. 13. The driving wheels are 5 feet 3 inches in diameter. This line has also some older engines of the type with 4-foot 3-inch wheels, which, although intended for goods work, are often used on passenger trains.

On the Brighton line a "goods"

FIG. 12.—ONE OF THE SIX-COUPLED "TERRIER" CLASS ON THE LONDON, BRIGHTON & SOUTH COAST RAILWAY

PHOTO BY G. J. PRENTICE

can travel sufficiently fast to run the fast trains on these services. A smaller class is employed on the Fenchurch Street-Blackwall trains. Some of these latter class of these engines, with 4-foot 6-inch wheels, was first introduced, but being found very suitable for passenger work, a new set of engines, with 5-foot wheels,

followed, painted passenger engine colours, and these are now the standard tank engines on the line. The North-Eastern engines of the type are not very best broad-gauge work of the period. Later these engines were converted to tender engines, and 8-foot wheels were substituted for the huge 9-foot wheels.

FIG. 13.—STANDARD TANK ENGINE ON THE LONDON & NORTH WESTERN RAILWAY. SIX-COUPLED RADIAL TYPE

PHOTO BY G. H. WILKINSON

numerous, but they are interesting as being two-cylinder compounds on the Worsdell-von Borries system. Other engines of the type do not need special description.

Of other six-coupled classes, the writer would simply mention, firstly, the Mersey and Wirral engines having six-coupled wheels and a trailing bogie, and, secondly, the Mersey engines having six-coupled wheels and both a leading and a trailing carrying axle.

But before concluding this necessarily brief summary, the writer would notice a few unusual designs which have been placed on the rails, with more or less satisfactory results. Among these the historical Bristol and Exeter 9-foot, double-bogie tank engines of the fifties must have first place. Designed by Mr. Pearson for work on broad-gauge metals, these engines were unique. Yet they were by no means failures, and to them has been attributed some of the These engines were always favourites with Great Western travellers.

Mention should be made also of Mr. Webb's compound classes on the London & North-Western Railway. Some of the Metropolitan type engines already referred to were so adapted, the coupling rods being removed and the high-pressure cylinders being made to drive one pair of wheels and the low-pressure cylinder the other pair, according to Mr. Webb's system. Then some of the six-wheeled, four-coupled engines and some of the double-enders were similarly adapted.

Finally a four-coupled, single-driving, eight-wheeler goods tank engine appeared. This marvellous machine had a leading carrying axle, a single pair of wheels driven by the inside low-pressure cylinder, and then four coupled wheels driven by the high-pressure cylinders. It was thus a six-driver tank, or a combined single-driving and a four-

coupled engine,—certainly a strange arrangement. All of these engines have been reconverted to simple engines or "scrapped." The only compound tank engines now remaining are those on the North-Eastern and on the Belfast & Northern Counties railways, already mentioned.

As to the future of the tank engine, in the writer's opinion it will be a great one, unless the steam locomotive be ousted prematurely by electricity. There will be only four types, probably only three. First, the ten-wheeled, four-coupled engines of the "Tilbury" type for the faster work, which may be developed to the double-bogie type by the substitution of a bogie for the trailing axle. Second, the six-coupled radial type for ordinary passenger work, and with smaller wheels for local goods traffic. Third (doubtful), the four-coupled-in-front-trailing-bogie class for lighter work and for general work, as long as it can hold its own against the preceding type. Fourth, the six-wheeled, six-coupled engines for use as shunters.

THE FOUNDRY CUPOLA

AND HOW TO MANAGE IT

By Robert Buchanan

Mr. Buchanan's dissertation on the foundry cupola as given in the following pages is a slightly condensed reprint of a paper entitled as above, presented recently before the Staffordshire Iron and Steel Institute. It is an admirable contribution to the literature of an important subject —THE EDITOR.

THE foundry cupola, considered as a furnace, is unique in simplicity of form. It consists of a vertical cylinder, lined with fire-brick or other refractory material, having openings, called "tuyeres," by which the blast enters; a door through which the coke, iron and limestone are charged, called the "charging door," and a small hole at the bottom through which the molten iron is drawn off, called the "tap hole." There is also a door on the side at the bottom through which entrance is made to fettle the cupola and to make repairs when necessary, and through which the kindling is put at the beginning, and the *debris* is drawn at the end of the cast or melt. This bottom door is made up previous to the blast being put on, so as to be proof against any metal getting through. That is the cupola in its simplest form, as used in hundreds of foundries to-day.

The modifications of the short, vertical cylinder, with two blast pipes, which have had any permanence are these:— (1) Heightening the cupola, by increasing the distance between hearth and charging door; (2) Having a blast belt, and, connected with the blast belt, double and sometimes triple rows of tuyeres; (3) Internal modifications of the sections of cupola containing the tuyeres, by which the blast of air reaches the centre of the fuel forming the bed.

Before lifts or hoists were in general use founders necessarily had to keep their cupolas sufficiently low, so that pig-iron, scrap-iron, coke, etc., could be elevated to the charging platform by manual labour. This system obtains in many foundries to-day, and such foundries are necessarily compelled still to use short cupolas.

The introduction of hoists made the lengthening of cupolas between hearth and charging door a simple matter, and so the advantages due to such lengthening could be readily obtained. These advantages are principally the utilising of the heat not directly expended in melting to heat the descending charges of iron about to be melted, and in keeping a cool charging door for the men to work at.

The increase of distance between hearth and charging door brought into effective use double and triple rows of tuyeres, with the better distribution of blast, more rapid combustion and quicker melting.

Double rows of tuyeres may be used, of course, on cupolas measuring 8 feet to 10 feet between hearth and charging door, but in such the waste heat going up the stack would be excessive. Double or triple rows of tuyeres must be accompanied by increased height, so that the heated gases may part with the greater proportion of their heat before finally going up the stack.

If we consider the modifications in the interior of cupolas, we shall find that almost the only change which has taken place relates to the portion immediately above the hearth and terminating a few inches above the upper tuyeres. At this point there is an increase of diameter, and this is carried in a straight line to above the charging door. If any taper be given to the cupola lining, it should be in favour of an easy descent

of the charges; that is, the diameter of the cupola at the charging door should never be greater than it is further down. Although built straight, a gradual increase of diameter from charging door to melting zone takes place in all cupolas, caused by the abrasion of the solid iron upon the heated brickwork, and by the heat of the melting.

There is a common belief amongst foundrymen that the contraction of a cupola at the tuyeres is primarily intended to reduce the quantity of coke necessary to form the bed for the first charge of iron. That is a very important function, no doubt, and not to be undervalued; but the greatest benefit obtained is that of getting the blast right to the centre of the cupola. This results in a very intense and rapid combustion over the whole area of the circle, and not simply a local combustion in front of each tuyere. In lining such a cupola, and afterwards in fettling it, care has to be taken that the change from the small to the large diameter is made with a gradual slope and not by a sudden change from the one diameter to the other, thus forming a circular shelf on which the descending coke may hang and so leave the space in front of the tuyeres hollow. In such a case the result would be a " bunged-up " cupola. This is caused by the slag being cooled by the blast, with the result that it solidifies across just where the reduced diameter begins.

For successful work the slag in all cases must retain its fluidity as it drops past, and away from, the cooling action of the blast. The reduction of diameter mentioned is really a lengthening of the tuyeres towards the centre of the cupola, and we get an intense combustion, beginning 4 to 6 inches above the top tuyeres, if two or more rows of tuyeres be in use, and extending over all the circular area of the cupola.

A double row of tuyeres gives the necessary tuyere area for the entrance of the blast, and will melt more quickly than tuyeres of equal area congregated at one level. The higher tuyeres supply the oxygen necessary for the combustion of the carbon monoxide generated immediately above the lower tuyeres, the completed combustion taking place in the melting zone.

The melting zone of a 36-inch cupola, with two rows of tuyeres and blast pressure of 8 oz., begins at about 6 to 8 inches above the upper tuyeres, and extends vertically for 24 inches and then terminates abruptly.

One row of tuyeres of suitable area will melt perfectly hot iron, but will do it much more slowly than two rows of tuyeres. Two rows of tuyeres melt hot and fast. Three rows of tuyeres will also melt hot and fast, but the upper or third row cuts up the lining badly and necessitates a deep bed of coke. Some maintain that no harm is done, although these upper tuyeres have no coke in front and blow onto the iron. The idea is that the carbon monoxide which may be escaping from the melting zone, unconsumed, is met by this stream of air and is burned to carbon dioxide, thus securing the economy of complete combustion. But it is doubtful if complete combustion in the cupola is wholly economical. On the contrary, a margin or slight excess of free carbon monoxide will ensure that the oxidisation of the iron and the metalloids we value present in the iron is reduced to the lowest degree possible.

If a third upper row of tuyeres is to be used, then the pipes leading to such tuyeres should be of very small diameter, —not exceeding 1 inch, and should connect to a tuyere of 2½ inches to 3 inches diameter, so that the air may enter the cupola at reduced pressure and thus minimise the cutting action of the flame at that place. The disuse of a third upper row of tuyeres does not affect the consumption of fuel adversely, retards the melting speed but slightly, and avoids a very rapid destruction of the lining.

The appearance of the flame at the charging door, when melting is being done, is an excellent index as to whether the cupola is being worked to the best advantage. The cupola stack or chimney should be of sufficient area and height to take away all the escaping gases and flame from the charging door,

and so help to make more comfortable the charging of the cupola, which, under the best conditions, is always a laborious operation.

The cupola should be high enough between the upper tuyeres and charging door to allow the ascending flame and products of combustion to part with their heat to the descending charges of iron and coke. Except during the final twenty-five or thirty minutes, when charging has ceased, the lining of the cupola at the charging door should not be hotter than a black-heat, or, at most, a dark-red heat.

There should not be, as is so often seen, a continuous flaming up through each topmost charge put on. This continuous flaming-through is to be avoided as being a waste of heat. It is a combustion which should take place very much further down the cupola, and is indeed rendered possible only by the charges of coke being sufficiently large to stand this waste of heat and yet have enough calorific power left to do the work required in the melting zone. It is a "consummation devoutly to be wished" that the coke would descend, only gently warmed, to within 2 feet of the melting zone, there to begin to redden up ready for the work of melting, shortly to begin. For coke to get red-hot, perhaps 8 feet above the melting zone, is a gross waste of fuel, heat, and money. In hot weather it also makes the position of the men charging the cupola almost unbearable.

We may also attribute the flaming through the upper charges to deficient blast, or blast badly distributed, and the same result will ensue with a cupola which is too short. There may be flame in the stack immediately above the charging door; in fact, there usually is such a flame, but the heat from it causes little inconvenience. This flame is the burning of the carbon monoxide, probably from the incandescent coke just above the melting zone, and is characterised by a bluish-pink colour, the flame clinging to every little projection and ledge in the chimney stack. When the flame in the chimney is of this bluish-pink tinge, the blue predominating, the flame clinging to the chimney wall as mentioned, now and again running down and burning at an opening in the charge in a ragged sort of way, then it is scarcely necessary to look at the metal being drawn from the cupola. Such an appearance at the charging door always betokens that good melting is being done. A flame of a whitish-yellow colour, extending through the charge and up into the chimney, and often out at the top of the chimney, and without the ragged appearance of the proper flame, indicates that too little air is being blown into the cupola. This flame may be seen in a cupola with proper blast any time the cupola-man opens a tuyere to clear away any obstruction there may be in front of the tuyere, and so allows some blast to escape, thus temporarily reducing the blast pressure. This flame is also an indication of scaffolding or other obstruction to the free passage of the blast. When this flame appears, and the blast gauge indicates a rise of pressure, then it is well to see if scaffolding has begun.

The appearances thus roughly indicated are such as apply to a cupola measuring 14 to 15 feet between tuyeres and charging door, and give, as indicated, a good idea of the general conditions obtaining in the cupola at the particular moment.

The total tuyere area to be economically employed depends upon the diameter of the cupola, the blast pressure available, and the density of the coke used. Whatever be the diameter of the cupola, it is desirable to have the blast effective over its whole area. If the diameter be large, then a higher pressure of blast with a reduced area of tuyeres may be used effectively to reach the centre of the cupola; but the coke must be hard and dense to be satisfactory under such conditions. With a softer coke the tuyere area has to be enlarged so that the proper volume of air may enter in a given time. This stream of air being slower and having a larger surface contact as it enters the cupola, has not such an abrasive action on the incandescent coke as the stream from a small tuyere, but neither has

it the penetrating power of the latter.

Should the tuyeres be set for high pressure of blast and dense coke, and coke of low density be delivered by the makers, as will sometimes happen, it is best to blow with less pressure. Melting will be slower, but the cast may be got through, though later than usual. Hard blowing with soft coke results in the bottom part of the cupola in front of the tuyeres being blown hollow, a solid roof of set slag a few inches above the tuyeres, a "stuck" cupola, and a general mess. There is no single thing which can happen in foundry operations which so closely affects everyone as a "stuck" cupola. It is a serious financial loss to both employer and employed, and raises a grave suspicion of the capacity of the management should it be anything but a rare occurrence. On the other hand, there is room for just a little legitimate pride when one has mastered the varying conditions attaching to cupola melting, and made the cupola a willing slave, answering to every call upon it.

The total tuyere area to be used on a cupola is given by West as not less than one-ninth the area of the cupola. That is a rule which does not err by being too small a proportion. No general rule, however, can be given for all conditions of diameter and height of cupola, pressure of blast, and character of coke used. The most suitable tuyere area for a particular cupola can be obtained only by trial. The suitability of the particular tuyere area adopted is to be judged by the results as a whole, the most important features of which should be hot and fast melting with the smallest quantity of fuel.

Cupola shells, unfortunately, have often much too small an opening for the passage of the air from the wind belt into the interior of the cupola. These openings in the inner shell should be amply large. It is easy to lessen the tuyere area, if it be thought well to do so, by making the opening in the brickwork less than the opening in the shell. If, however, one wants to blow with a 5-inch tuyere, and the opening through the shell is only 4 inches, there is unnecessary trouble and expense in making the trial.

The doors on the air-belt opposite the tuyeres should also be ample in size, being not less than 6 inches in diameter, with a 2-inch opening in the middle of the large door, this opening being covered by a small door conveniently hung, so that the tuyeres may be poked as occasion requires without having to open the large door and so allow an unnecessary amount of blast to escape. The small door may also be used as a peephole to see whether the tuyeres are clean. The glass and mica usually seen on tuyere doors soon break, or become opaque through the impinging of particles of dust propelled by the blast. The use of the large tuyere doors will be seen when we come to speak of "scaffolding."

The height at which tuyeres should be above the bottom of the cupola is fixed by the weight of the castings to be cast in the foundry, and also by a consideration whether a "receiver" or separate hearth is used in which to collect the metal as it is melted, or whether the iron is collected in the hearth of the cupola itself. In the case of cupolas having receivers for collecting the iron as it melts, the lower tuyeres may be only four inches above the bottom. The metal and slag run directly out of the cupola into the receiver as quickly as melted, and so the lower tuyeres may be as low as desired, provided that the channel-way into the receiver be just a little lower.

In cupolas where the metal is collected in the hearth of the cupola itself the height of the lower tuyeres, whether double or single rows of tuyeres be used, should be governed by the class and weight of castings being made, as already mentioned, and also, to some extent, by the duration of the cast.

The writer has seen a description of a cupola having no separate hearth, where the tuyeres were said to be only 4 inches above the bottom. With such a height of tuyeres the melt would be an exceedingly small one, as the accumulated slag would speedily close the tuyeres. It has been found that melting

with a cupola 24 inches in diameter, having tuyeres 24 inches above the bottom, slag would sometimes appear at the tuyeres with 2 cwt. of melted iron in the hearth, 40 cwt. of iron having been melted and no slag run off.

A cupola with tuyeres less than 12 inches above the bottom is suited only for hand-ladle work, and even at that height the continuation of the melt will depend on a careful watch being kept on the slag, which should be run off at the slag hole, if there is one. If there is no slag hole, the slag may be run off at the tap hole, but that is an unworkmanlike way of doing it. Every cupola should have a slag hole and it should be used.

The reason for placing tuyeres only a short distance above the bottom is, of course, to lessen the amount of coke necessary for the bed. This must extend at least 12 inches above the highest tuyere, whether single, double, or triple rows be used. It is very doubtful saving to work with tuyeres so low as to be in constant danger of getting them and the air passages filled with slag, and perhaps iron. There is also the risk of drawing off the pig-iron and scrap in separate strata, some castings getting all pig-iron and others all scrap, instead of the well-mixed iron which may be obtained from a hearth of proper depth.

If low tuyeres and a restricted bed of coke be used, a fair measure of intelligence, skill, and alertness must be displayed at the cupola if satisfactory results are to be obtained.

BLAST PRESSURE

Iron may be melted as hot with blast at 6 ounces of pressure as with 12 ounces, but the speed of melting will be reduced. The greater the diameter of the cupola, the greater will be the loss of combustible gases when using a soft blast. As the diameter increases so should the blast pressure increase, so that it may reach the centre of the cupola. If there is a blast gauge, it should be seen that the cupola-man is shown its use and that he consults it. Unfortunately, there are hundreds of cupolas melting to-day in charge of men who never saw a blast gauge, and who would not know what it indicated if they did see it. There should be a blast gauge at every fan or blower, and one on every cupola. The blast gauge is an excellent telltale of how the cupola is working If the cupola-man observes that the blast gauge is registering 5 or 6 ounces more than usual, he is not to conclude that the blower has become much more effective than usual. He should take the rise in the gauge as a danger signal, and should see if, as is most probably the case, there is a partial scaffolding in the cupola, and at once take steps to clear it.

SCAFFOLDING, AND HOW TO AVOID IT

Scaffolding is the term used when the charges of coke and iron have ceased following down as the coke and iron previously charged are burned away and melted, respectively. When scaffolding occurs in a cupola there is usually a fairly empty space in front of the tuyeres. Over the tuyeres, however, and extending almost, if not quite, across the cupola, is a roof of solidified slag and iron. Scaffolding may be due to deficiency of fluxing material, such as limestone or fluorspar. Under such conditions the slag formed is pasty and not truly fluid, with the result that when it comes within the action of the blast as it enters the hearth it becomes solid.

Poor coke, having low carbon, high ash, and low density of structure, otherwise a light coke, is a fruitful cause of scaffolding. The low carbon does not give that intensity of heat so desirable, the high ash gives excessive slag, and the lightness of structure allows the coke to be readily disintegrated or blown away by the blast. Faulty contour of cupola lining, possibly in conjunction with the causes just mentioned, may cause, or help to cause, scaffolding. All departures from vertical lines, or where cupola linings are being drawn in at bottom, should be done very gradually, and anything in the nature of a shelf carefully avoided. Blowing a cupola with too much blast may also cause scaffolding, but that is a compara-

tively rare cause where good coke is employed.

The way to avoid scaffolding is to have ample fluxing material, say fifty-six pounds of limestone per ton of iron melted. If charges are all pig-iron, forty pounds of limestone per ton of iron melted is enough; but, then, few founders use all pig-iron. Use good coke, with carbon as much over 90 per cent. as can be got at a moderate cost. The lessened melting power of a coke at 87 per cent. carbon is very marked as compared with coke with 90 per cent. carbon. It takes 27 cwt. of the 87 per cent. coke to supply as many carbon units as is contained in 26 cwt. of coke with 90 per cent. carbon. Ash usually takes the place of carbon in low-carbon cokes, and it is a very poor substitute. The only place where it is as effective is on the weighing machine. If low-carbon coke must be used, and scaffolding is to be avoided, then ample fluxing, light charges of iron and easy blowing are the means to adopt.

If a piece of pig-iron or heavy scrap has got down in front of a tuyere, it forms an excellent starting point for scaffolding. The large door in front of the tuyere provides a means by which some pieces of coal may be placed in the inner end of the tuyere, against the hottest fuel or slag there, so that the coal may begin burning. If the pig-iron or scrap (it is usually a piece of pig-iron) blocks the way, then it must be poked back towards the centre of the cupola, so that the coal gets alight. The tuyere is now closed and the blast allowed to blow the lighted coal. Such a course has usually a magical effect in clearing the tuyere, as the flame from the coal is very hot.

A large door to the tuyere allows the coal to be put into the tuyere by hand. With a small door the coal has to be thrown across the air belt, with the result that about one piece in six goes where it is wanted. If the unmelted pig-iron or partial scaffolding cannot be moved back by the steel bar in the hands of the cupola-man, then the tuyere should be closed by means of ganister or other suitable material, and the other tuyeres be made to melt down the obstruction. The blast should be eased while this is being done and not put on full until, by poking a hole in the tuyere closed with ganister, it is seen the obstruction has gone. The tuyere may then be fully opened and the blast put on with full force, and melting proceeds as before.

If several tuyeres have got black and the obstruction cannot be moved by poking, nor by adding coal, nor by stopping tuyeres, you may conclude that the cupola is in a "parlous state." In such a contingency shut off the blast at once, as more air is only cooling the cupola and making it more difficult to get the coke and iron out. The cupola-men may then experience the delights of getting the coke and iron, some of it half melted, out of a "bunged" cupola. Fortunately, it is a very satisfying kind of pleasure. One experience of the kind perfectly satisfies all engaged in it, and there is no longing for a renewal of the joys which always accompany a "bunged" cupola.

Putting extra limestone or other flux on the topmost charge is of use only if the scaffolding is cleared and melting is proceeding; in this case the added limestone as it reaches the melting zone will render the slags being formed there more fluid, and so help to clean down the walls of the cupola.

If the cupola has to be fettled next morning, the cupola-men, with anxious forethought as to how hot it will be, will sometimes, if allowed, throw quantities of water through the charging door onto the hot brickwork and thus ruin the lining. A better plan is to close the charging door for the night and allow the air to travel the whole length of the cupola from bottom to top. Leaving the charging door open in the expectation that it will let out some of the heat is a mistake; it only spoils the draught to be obtained by the unbroken continuity of cupola and chimney.

It may be useful to compare the relative drawbacks and advantages of cupolas with solid bottoms, collecting the metal in their own hearths, and those with drop bottoms and separate hearths.

Cupolas which have solid bottoms and collect metal in their own hearths are less expensive to erect, less costly in upkeep of lining, etc., and require less fettling daily. The coke has to heat up, say, 30 cwt. less of brickwork than in the case of a cupola having a receiver, and so has that heat to bestow on melting. A given quantity of coke should thus produce hotter metal at the tap hole of a self-contained cupola than will be tapped from one having a receiver, and this is undoubtedly the case.

The tuyeres of a self-contained cupola, however, as already pointed out, have to be high enough to allow a body of metal to be collected in the cupola, and this causes the bed of coke to be higher than is necessary in a cupola having a receiver.

Contracting the cupola in the region of the tuyeres so as to get blast penetration also reduces this capacity for holding a quantity of molten iron. In this respect the cupola with a receiver has an advantage. No metal being collected in the cupola, the size at the bottom may be reduced very considerably, and so the coke used for the bed may be lessened accordingly.

Cupolas having receivers allow a more perfect mixing of iron, as a large quantity may be collected in the receiver with no risk of having trouble with iron or slag getting into the tuyeres. This collecting and perfect mixing of the iron is the outstanding advantage of the use of a receiver and renders possible the drawing in of the cupola, as mentioned. It has no other advantage. Besides, the channel-way or connection between cupola and receiver, through which all the iron and slag flow, is a distinctly tender part. A deep groove is worn in the bottom of the channel each melt. If a crack develops and the metal begins to come through, and in doing so proceeds to cut up the iron casing, it is almost impossible to go on melting.

The writer has found it best not to run the metal along the main connecting brick. By bedding good fire-bricks end to end along the channel, and renewing these as they are worn out, a very much longer service is got from the main brick. Should the metal get between the joints of the bricks it can get no further than the connection or main brick on which they lie. Should the connection brick be cracked, say, by a movement of the receiver (and in heating and cooling this is not unusual), then by making one of the fire-clay bricks span the crack the connection brick may be made to do service until it can be suitably replaced.

To sum up in a few sentences what has been stated, a cupola which collects the metal in its own hearth will melt metal more economically than one having a receiver, but will require higher personal skill in management to produce well-mixed iron. A cupola having a receiver takes more fettling to keep in order, is not so economical of fuel, having a larger body of brickwork to heat up, but gives more perfectly mixed iron.

Cupolas with drop bottoms are not very common in Great Britain, most founders preferring those with solid, brick-built bottoms, the coke, slag, etc., being drawn out at the side door at the bottom at the conclusion of the cast. Some who have had drop bottoms to their cupolas have even discarded them and built solid bottoms instead. Drop bottoms are in almost universal use in the United States.

Drawing a cupola by the side door at the bottom at the conclusion of a cast, as is necessary in cupolas having solid bottoms, is laborious, hot work at the end of a hot day. With a drop bottom the contents of a cupola may be withdrawn in two minutes without any effort worth mentioning. On the other hand, the drop bottom has to be made up each day, and made up carefully and well. A solid-bottom cupola requires practically no making up whatever. When metal happens to make its way down through the folding doors of a drop bottom, as will sometimes happen, there is no necessity to drop the cupola. As a general rule, shutting off the wind and stopping melting permits repairs to be made and the leak stopped so that the heat can be finished.

One material advantage which the drop bottom has over the solid bottom

is when more iron has been charged into the cupola than is necessary to cast the work then on the moulding floor. When all the iron required has been tapped out, the blast may be turned off and all the unmelted iron and unburnt coke in the cupola dropped, the coke being carefully quenched, to be used again the following day. In such a case when using a cupola with solid bottom the cupola-men almost always melt the iron and pour it on the floor. It has then to be broken up, is accounted as scrap, and is charged into the cupola as such. The coke used in melting this excess iron is consumed, of course, and is not again available. The cupola-man's motive for doing so is not to waste the coke or iron but is simply that for him the easiest way to get out of a solid-bottom cupola iron which is already in is by melting it out.

Charging exactly the quantity of iron required is excellent foundry practice, but having 1 cwt. less than is required is very bad practice indeed, and may result in the "pouring short" of an important casting. If there is any doubt of the quantity of metal in the ladle being sufficient for the mould to be cast, and no more is to be had, then do not hesitate to pour the metal into pigs made in the floor. It is the stupidest of proceedings to follow an error in judgment at the cupola by turning a good mould into a very indifferent pig bed. That is what is done when a mould is poured with too little iron, and it is not at all an unknown thing in foundries.

A few hundredweights of iron in the cupola in excess of the probable requirements are thus used as a factor of safety, and, as already pointed out, the drop bottom allows this margin of safety to be obtained at the cost only of picking out the iron and coke from the *debris* of the cupola and again raising them to the cupola platform.

One additional advantage of the drop bottom is the easy access it gives to the interior of the cupola for fettling purposes. There is thus a clear balance of advantage in favour of the drop-bottom as compared with the solid-bottom cupola for ordinary foundry work.

CUPOLA MANAGEMENT

Iron may be melted with a very low ratio of coke to iron and yet not be economically melted. If the iron is not fluid enough for the particular work to be cast then a small consumption of coke per ton of iron melted has been waste and not economy.

Cupolas are too often left to be managed by practically unlettered men, to whom "use and wont" are the only safety, and deviation spells disaster. To look to such for an advance in cupola practice is folly. One of the things we hope the future contains is that no one shall be put in charge of a foundry who cannot himself, in some considerable degree, supply some of that higher knowledge which fate or Providence or whatever you will has denied to those under him.

An important quality necessary in one who aspires to successful cupola management is a knowledge of the material with which good results are to be obtained. For this purpose he should know the general effect of the several constituents present in pig and scrap iron, the modifications which these undergo during their passage down the cupola, from the solid to the molten condition, and the effect of the constituents upon the general condition of the casting produced. It is here that the chemist and founder may co-operate towards that desired end. Chemistry may not be an infallible guide nor may it account for some of the unexplained phenomena seen in the manipulation of iron into the finished product, but it will certainly prove of help in many instances.

Is the fracture of pig-iron a guide to its quality? The reply is "Yes" and "No." Fracture has been, and is now, the only guide which most founders have regarding the quality of the irons they use. However, it is inevitable that judging pig-iron by fracture shall give place to the more precise test of analysis. Physical structure may sometimes differ in irons of similar analyses and discordant results follow tests of these irons,

but the broad fact remains that in the very great majority of cases the same physical effects follow the same chemical constitution.

Analysis shows the vagaries of the numbering of iron. The No. 1, No. 2 and No. 3 of one maker are not the No. 1, No. 2, No. 3 of another maker, and sometimes to help to complicate matters one maker's irons will change numbers. Why should there not be a chemical test for each cast and a sale on that test? Founders have a right to expect that a pig-iron of a given brand and number should have some consistency of character, yet we all know from experience that this is not the case. Such differences may be unavoidable in blast furnace practice, but the iron founder must recognise that they exist. Knowing the chemical contents of the iron, the manager of the cupola is helped to produce, with a regularity obtainable in no other way, a mixture of iron in which are found the qualities necessary for the work in hand. If he has no definite data, how can he produce definite results?

Coke should also be bought by analysis, supplemented by due attention to density of structure. Ash and sulphur should be as low as can be obtained, and even in coke of good reputation these vary considerably. Taking ten analyses of coke, the results were as follows:—

	Sulphur	Ash
Lowest percentage	0.530	6.520
Highest percentage	1.068	10.300
Average percentage	0 769	8.604

The coke with 1.068 per cent. sulphur caused much trouble by hardening the castings. Coke with 90 per cent. carbon may be considered satisfactory in this respect. Carbon should not be allowed to drop below 86.5 per cent., as even at this percentage a marked difference in the melting power is noticeable, as may be expected. Coke with 91.78 per cent. of carbon is the highest carbon the writer has met with.

Limestone used for fluxing should also be analysed, as a small difference in composition may alter considerably the character of the slag either in the molten condition or when hard and adhering to the lining of cupola and ladles.

ANALYSES OF LIMESTONE

	(1)	(2)
Calcium carbonate	98.02	95.01
Magnesium	1.05	----
Silica	.43	4.16
Alumina	.20	.40
Oxide of iron	.23	.43
Oxide of manganese	.07	----
	100.00	100.00

The limestone marked (2) formed a slag remarkable for the difficulty with which it was detached from the walls of the cupola and receiver when chipping down preparatory to fettling for another cast. The limestone marked (1) was superior to the other in respect of the high percentage of calcium carbonate and comparative freedom from silica.

SCRAP IRON

In mixing iron according to the analyses of the several irons to be used, the scrap iron coming from the foundry as gates, rejected castings, etc., is readily classified as to its position, being similar in analysis to the castings produced. Bought-in scrap from its miscellaneous character forms the most doubtful part of the whole. Heavy machinery scrap may be considered as having silicon 1.8 per cent, phosphorus 0.8 per cent., sulphur 0.11 per cent. Miscellaneous light or medium scrap may be considered as having silicon 2 per cent., phosphorus 1.2 per cent., sulphur 0.11 per cent.

In the sample mixture given in the table on the next page, silicon, phosphorus, and sulphur are taken as being the constituents of greatest importance in the castings designed to be made. In some classes of work other constituents may rise into prominence, and one or other of these may be relegated to a position of secondary importance. This simple mixture, by the analytical method, is chosen not because it is particularly accurate, but as an exact representation of what may be done in daily work.

To get the average silicon divide 26.953 by 10 and deduct 0.25, being the average amount of silicon loss in the course of one melting of iron. To get the average phosphorus divide 9.596 by 10, but as phosphorus does not lose or gain anything in the course of melting,

SAMPLE MIXTURE

PIG IRON	Cwt.	Silicon	Total Silicon	Phosphorus	Total Phosphorus	Sulphur	Total Sulphur
Holwell No. 3	2	3.546	7.092	1.141	2.282	0.029	0.058
Stanton No. 2	2	3.826	7.652	1.092	2.184	0.025	0.050
Barrow XXX	1	1.959	1.959	0 285	0.285	0.070	0.070
Hematite	1	2.250	2.250	0.045	0.045	Trace	Trace
Scrap	4	2.000	8.000	1.200	4.800	0.110	0.440
	10		26.953		9 596		0.618

nothing is added or deducted. To get the average sulphur divide 0.618 by 10 and add 0.038, being the average gain of sulphur in the course of one melting. The figure 10 represents, of course, the number of cwts. making up the charge. The result, as checked by the analysis, is as follows:—

	Estimate	Analysis	Difference
Silicon	2.445	2.519	0.074
Phosphorus	0.950	0 868	0.091
Sulphur	0.099	0.104	0.005

By making mixtures in this way one can usually get very near the exact constitution of the product so far as a chemist can reveal it. One could not have the same exactitude mixing irons by fracture. There is also this immense advantage to the founder. He is not tied to the use of any one make of iron, but may make his mixtures with confidence, whatever the name or brand, so long as the combination yields the requisite percentage of each constituent.

The use of test bars is a valuable adjunct to such a system of mixing. Both test bar and analysis will be found to have a very vital relationship, of which indeed there is abundant proof, and so require no further consideration at this time.

Having begun the mixing of iron as shown, it is continued by the pig-breaker. Where several stacks of one brand of iron are in the yard, those having come in at several different times will represent very probably several casts at the blast furnace. Each day's requirements should be drawn from several of these stacks so that a truer average quality of the iron may be obtained. Another good system is to lay one long layer of pig-iron from the first car; on top of that put the pig-iron from the next car, and so on. Then begin using at one end and work from top to bottom. Thus the pig-iron is getting well mixed before it reaches the cupola, and helps considerably to regulate the quality.

CHARGING THE CUPOLA

We shall take it that the bottom of the cupola is in good order and the inside contour of lining free from sudden changes of diameter or projecting knobs of slag, which may hinder the regular descent of the charges of coke and iron as melting proceeds. The first thing to do is to ascertain the depth of bed necessary to begin the melting. It is the upper part of the bed which melts the first charge of iron. The coke in front of the tuyeres does not melt the iron, unless it be indirectly.

When the blast strikes the coke immediately in front of the tuyeres, carbon dioxide, or carbonic acid, is formed. The carbon dioxide so formed, passing up through the next layer of incandescent coke, is immediately reduced to carbonic oxide, which, combining with the free oygen of the blast, produces the intense heat of the melting zone and passes up the cupola as carbon dioxide. There is also some unconsumed carbonic oxide which escapes up the cupola, and is to be seen burning in the chimney or stack. The presence of unconsumed carbonic oxide in the cupola is not altogether an evil, as it prevents, in some degree, oxidation of the iron. The melting zone is the section of the cupola where the combustion of the carbonic oxide is practically begun and completed with the production of a most intense heat.

The region of highest temperature, as indicated by the wear of the lining, is at the top of the melting zone. The position and depth of the melting zone is fixed by the quantity and pressure of blast used, but may vary to some extent as tuyere area and cupola diameter vary.

It is a most important fact to remem-

ber that no actual melting takes place until the metal reaches the top of the melting zone, no matter how much coke is put on above the zone. Were it piled 4 feet high, the coke is simply burned away until the iron gets down to the melting zone. where it changes from the solid to the liquid state, and so drops to the hearth.

Not any more coal than is actually necessary should be used in kindling, as ordinary coal usually contains more sulphur than is desirable, and tends to harden the first iron melted. Many cupola-men make the mistake of overburning the bed before making up the bottom door and beginning charging.

The bed requires to be kindled as high as the tuyeres, and that only, and charging the iron may then begin. The pig-iron, which has been broken into four pieces if for a cupola of over 30 inches in diameter, or into six or eight pieces for lesser diameters, is weighed and charged into the cupola. It is a good plan to put a thin layer of scrap on the top of the bed to keep the solid pig-iron from smashing the upper layer of coke. Then, after the pig-iron, the remainder of the scrap is charged and evenly distributed over the cupola. On the scrap is now placed the charge of coke, also evenly distributed. Some limestone, to flux the ash of the coke and the sand adhering to pig-iron or foundry scrap, is now added. Some cupola-men, however, do not begin adding limestone until the first charge after the cupola is filled up, but I fail to see any advantage in this.

The charges as stated are continued until the cupola is full to the charging door. It is important that the coke occupies a distinct stratum between the charges of iron, as only by this means is the bed kept level as melting proceeds. Projections inside the cupola may also tilt a part of the charge, and so cause an irregular descent to the melting zone. Level charging and a level descent of the charges go a long way towards satisfactory melting. When the cupola has been charged to the charging door the blast may be put on as soon as is convenient. Some people advocate a period of one or two hours as a proper time to elapse between finishing charging and putting on the blast.

The writer has found no inconvenience whatever in blowing as soon as charging is finished, if the bed is kindled to the tuyeres, and no cupola should be charged unless it be kindled to the tuyeres. Blowing quickly after charging will give hotter first metal than would be obtained with a longer interval of time. When the coke is called upon to give up its heat, it should do so rapidly and with its whole vigour, and should not be employed in "warming the charge," as it is termed.

The quantity of coke put on between the charges should be only sufficient to keep the bed level with the top of the melting zone. When a charge of iron has been melted and the layer of coke has followed down by reason of the weight of iron and coke on top of it, if the coke be too great in quantity and more than replaces the coke consumed in melting the iron just liquefied, the result is a partial cessation of melting until the excess coke is burned away and the iron is down to the top of the melting zone. By the time the charge of iron has melted, the fuel in the melting zone will have sunk a distance which depends on the weight of the charge of iron melted. The charge or layer of coke which follows should exactly fill the space vacated by the coke used in melting the previous charge.

Were the important facts understood, that iron is melted only in the melting zone; that coke intervening between it and the melting zone is simply burned away; that the sinking of the incandescent fuel in the zone wants replacing and no more, then melting would be more rapid and very much more economical than it usually is at present.

It will readily be understood how it is that charges of coke which are too large cause the melting to be slow and hot, slow because the iron cannot get down quickly enough to the only place where it can be melted; and hot because of the excess of fuel. The excess fuel, for want of something better to do, usually cuts up the lining.

Each cupola may be put upon the best melting conditions only by trial. To do so, in the morning before fettling is done look for the melting zone of the previous day. Measure the distance from the top of the zone to the sill of the charging door. Saw a length of wood a foot shorter than the distance found. Charge the coke until the piece of wood, resting one end on the coke, comes just level with the sill of the charging door. The coke has been weighed, of course, and it will be found that it takes more coke each day, as the lining wears, to bring the bed up to the same height as tested by the measuring stick.

A thorough fettling each week brings the cupola back to the original form, and so there is soon established a system of regular height of bed. Do not let the cupola-men depart from weighing the bed and all charges of coke. They may profess to know the weight they shovel on, but they don't.

If the melting is hot and slow, then the charge of coke on the top of each charge of iron is too large, which will be confirmed by too much flame of a luminous character at the charging door.

Reduce the quantity so charged, say, twenty-eight pounds each charge, and continue for a day or two charging the same way. If the metal is hot, and probably faster melted, again reduce the coke by another twenty-eight pounds per charge, and so continue until the danger limit is reached. This will be indicated by the metal getting dull at the end of the melting of one charge and hotter at the beginning of the next. This will not go on long, as the bed is now being called upon to contribute more to the melting than is being replaced by the charging of coke reaching it. The last deduction of coke should then be replaced and so continued.

The metal should now be of a regular heat, quickly and economically melted. When melting down the last two charges of iron, reduce the blast to half-pressure. It does not retard the melting appreciably, saves the coke remaining in the cupola, and avoids wasting the lining. More linings are wasted in the last fifteen minutes' blowing than for hours previously.

The following is the system for charging a 36-inch cupola, two of which, as well as a smaller one on special work, are in use at the Soho Foundry of W. and T. Avery, Ltd., Birmingham:—Inside diameter of cupola, 36 inches, contracted to 19 inches at bottom. Height, bottom plate to charging door, 15 feet. Two rows of tuyeres of 78 square inches total area. Melts over four tons per hour, and twenty and one-half tons have been melted in it in one afternoon. Each cupola has a separate hearth or receiver for collecting the iron as it is melted. From the receiver the metal is tapped into the ladles.

The system of charging may be best followed by beginning at the bottom and reading up.

Charge 10 cwt. iron Charge 1 cwt. coke	} and so on, until after the second last charge of iron, when only 56 lbs. of coke is put on.
Charge 10 cwt. iron Charge 1½ cwt. coke	} Cupola is full to charging door, when 50 cwt. of iron is in.
Charge 10 cwt. iron Charge 1½ cwt. coke	} Blast pressure 8 to 10 oz.
Charge 10 cwt. iron Charge 1½ cwt. coke	} 24 to 28 lbs. of limestone put on top of each charge of coke.
Charge 10 cwt. iron Bed 5 cwt. coke	

The average expenditure of coke over a period of one month is as follows:—

Light castings 1 lb. of coke melted 7.87 lbs. of iron.
Heavy cast'gs 1 lb. of coke melted 10.00 lbs. of iron.
Av. for month 1 lb. of coke melted 8.49 lbs. of iron.

The light castings are debited with the bed of coke. After the cupola is charged level with the charging door, the coke charged is at the rate of 2 cwt. per ton of iron charged, excepting the last coke put on, which is only fifty-six pounds between the last two charges of iron.

Metal appears eight minutes after the blast is put on, and is hot enough throughout the heat to run castings sometimes under one-eighth of an inch in thickness, moulded and cast at a distance of 250 feet or thereby from the cupola.

MELTING RATIOS

This is a subject which probably more than any other interests foundrymen, and in regard to it there is considerable

romancing by cupola makers and some others. Some of the absurd claims as to economy of fuel would only be fitted to make one smile did one not know that they too often seriously mislead people with capital invested in foundries. Their acquaintance with melting is not such as enables them to judge of the case, and so they accept such statements as authoritative. Misleading claims cause trouble and annoyance for people who have the melting to do and disappointment for those who employ them.

When absurd claims are made, say of melting sixteen pounds of iron with one pound of coke, one wonders what was done with the metal when it was melted. Did it run castings? That is the object for which iron is melted. What was the proportion of defective castings? It is as important to know the answer to these questions as to know the proportions of iron and coke. Metal may be melted in the ratio stated, but the writer does not believe that the castings of an average foundry can be run with the metal. What, then, is a good, that is, an economical, ratio of coke to iron? It cannot be stated in one word. What is good and economical melting under one set of conditions may be waste under another set of conditions. Condition of cupola, volume of blast, quality of coke and of the iron to be melted, kind of castings to be run, and distance the metal has to be carried are all important matters affecting the answer.

An economical melting ratio is one which, under the prevailing conditions, shall produce, with the smallest quantity of coke, metal suited for the work to be cast. Can all cupolas as now worked be considered as having economical melting ratios? Investigation would show, we have no doubt, that the number on which no improvement may be made is a small minority indeed.

EFFECT OF CUPOLA MELTING UPON THE IRON

That iron undergoes some changes other than being melted in its passage from the charging door of the cupola to the foundry ladle is known to most founders. Silicon always becomes oxidised to some extent, losing 0.20 to 0.30 per cent. each time the metal is melted. Manganese loses on an average 0.093 per cent. each time the metal is melted. The smallest loss observed by the writer is 0.056 per cent and the greatest, 0.134 per cent. The manganese in the castings averaged 0.259 per cent.

Phosphorus goes through the cupola practically unaltered in quantity. Blast and flux have little effect upon it, and one sometimes wishes they had more. The only phosphorus which passes into the slag seems to be that present in the iron which is oxidised, and which goes into the slag taking its phosphorus with it.

Irons containing 1 per cent. and over of phosphorus have great fluidity and running power, so that thin castings may be easily run with them. The fluidity and running power of such iron is due to the low melting point of phosphide of iron, which is the condition in which phosphorus is present in iron. This melting point is several hundred degrees of temperature under that of the iron through which the phosphide is interspersed. At the moment the iron melts, the phosphide has risen several hundred degrees above its melting point. This fact supplies the reason why phosphoric irons run with such fluidity; the phosphide has to cool down through many degrees of temperature, lower than the "setting" or freezing point of iron free from phosphorus, before reaching its "setting" or freezing point. The cooling action of a mould has thus an effect on low-phosphorus iron which it fails to have on phosphoric iron. Iron containing 0.20 per cent. of phosphorus we may term a low-phosphorus iron; iron containing 1 per cent. and over we may term a phosphoric iron.

Sulphur is the source of much trouble to the iron founder, hardening castings very considerably if 0.14 per cent. be present, and at 0.15 per cent. the iron is too hard to machine. Coke, with sulphur averaging 0.769 per cent., increased the sulphur in the castings as follows:—Minimum, 0.020 per cent.;

maximum, 0.079 per cent.; average, 0.038 per cent. The average is that of twelve meltings. As sulphur increases in the coke, so will it increase in the casting. The importance, therefore, of using coke with little sulphur cannot be too much emphasised.

If the cupola is melting dull iron, a greater proportion of sulphur goes into the iron than when hot melting is being done. The first iron from a cupola, not being so hot, usually, as that melted later, is higher in sulphur, and such iron is, therefore, used for castings with little or no machining to be done on them. If the cupola melts dull all through the cast, then the iron will, from this cause, be hard all through the cast. This absorption of sulphur by dull iron is evidently due to the slag being pasty, in which condition it has a feeble combining effect on the sulphur. Slag has a higher melting point than iron. The iron on melting combines with the sulphur, forming sulphide of iron, at a temperature under that of fluid slag.

If hot melting be done, the sulphur passes into the slag in greater proportion, not because the iron is hot, but by reason of the slag being fluid, and thus comes intimately in contact and combines with the sulphur-bearing ash of the coke. Thus it is that hot melting makes soft castings. Combined carbon and graphitic carbon need not be considered as being specially affected by melting. The respective amounts to be found in the castings are due more to the other constituents present and also to the cooling conditions of the castings than to any action which takes place in the cupola. Carbon, as a whole, is reduced in quantity in the course of melting, but an increase of total carbon is not unknown. However, this forms the exception to the rule. The loss of total carbon in one melting will probably range from 0.130 to 0.140 per cent.

CUPOLA SLAG

There is a section of cupola practice which has not had the attention it deserves. There is more iron, not visible to the eye, carried to the rubbish heap than most people imagine. So long as cupola-men get a fluid slag, the iron chemically combined with the slag does not concern them, principally for the reason that few of them know there is iron in the slag, unless it be visible. Slags may contain over 10 per cent. of iron, the lowest quantity of iron in any slags we have had analysed being 1.90 per cent. and the highest 10.10 per cent.

Taking nine analyses of slag, some of which were averages of three or four meltings, and would thus represent about twenty meltings, the results were as follows:—Average of iron, 4.690 per cent.; sulphur, 0.270 per cent.; phosphorus, 0.049 per cent. Silica averaged 57 to 58 per cent., and was the product of sand adhering to the pig-iron and foundry scrap, and also from the lining of the cupola.

Increasing the quantity of limestone charged does not seem to decrease the percentage of iron, nor to increase the sulphur and phosphorus passing into the slag in any appreciable degree. Thus, with lime at 0.60 per cent. in the slag, we found sulphur 0.219 per cent. and phosphorus 0.042 per cent. With lime increased 22.61 per cent., the sulphur is increased 0.001 per cent. and the phosphorus 0.008 per cent.

These are very small quantities indeed when compared with the effect one might expect with lime increased from 0.60 to 22.61 per cent. The slag, with 10.10 per cent. loss of iron, had also the greatest amount of phosphorus (0.16 per cent.), showing that the iron in combining with the slag had taken its phosphorus with it.

It has been already stated that when iron is being melted dull, that is, coming out of the cupola at what we may term the "red-molten" condition, a greater quantity of the sulphur goes into the iron than when hot melting is being done. This we explained as being due to the formation of sulphide of iron at a temperature at which the slag was pasty or only partially fluid. Although slag has been fluid in the cupola, and has taken up the normal quantity of sulphur, if it be allowed to cool in contact with

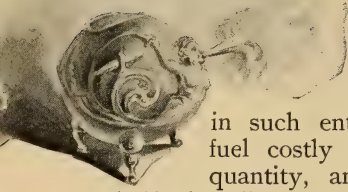
iron, it will give up a proportion of sulphur to the iron. Some iron, allowed to cool under slag during a period of 120 hours, had sulphur increased from 0.107 per cent. to 0.153 per cent., an increase of 43 per cent. At the same time, combined carbon had decreased from 0.508 to 0.020 per cent.

There is thus a temperature which, for want of more precise data, we shall call the "red-molten" condition of iron, at which the slag has a lower combining power for sulphur than iron has; and also there is a temperature at which, though the slag has already combined with the sulphur, it will pass some of the sulphur into the iron if they be cooled in contact. Melting hot is thus the means to adopt for best results, both in quality of iron produced and in fluidity by which the various castings may be run, each at its proper temper. If metal is produced of equal quality and fluidity each day, with a moderate expenditure of fuel, then you may conclude that intelligence and skill are directing the operations of the cupola.

If, on the other hand, there is hot metal one day and dull metal the next, and this is almost always accompanied by an extravagant use of coke, you may conclude that there is someone about who does not know how to work the cupola.

GAS-POWER PLANTS FOR MINING AND SMELTING

By Hawley Pettibone



THE large amount of power required in modern mining operations makes the power plant an important factor in such enterprises. With fuel costly and limited in quantity, and water scarce and of bad quality for steaming purposes, the selection of a power plant for a particular proposition becomes at once important and difficult. As conditions vary with the locality, each mining proposition has its own peculiar problems. These must be carefully studied and considered in selecting the type of power plant to be adopted, and it is not safe to follow even successful precedents until assured that all conditions are similar.

The successful operation of gas-power plants for mining and smelting introduces a new factor to be considered. A gas-power plant has been in operation about two years at Nacosari, Sonora, Mexico, operated by the Moctezuma Copper Company. All the power is generated at a central station with electrical distribution to motors about the works. The gas plant consists of two sets of Loomis gas generators, and each set will produce gas enough to supply power for the entire plant, one being in continuous service, with the other set in reserve, thus insuring continuous service.

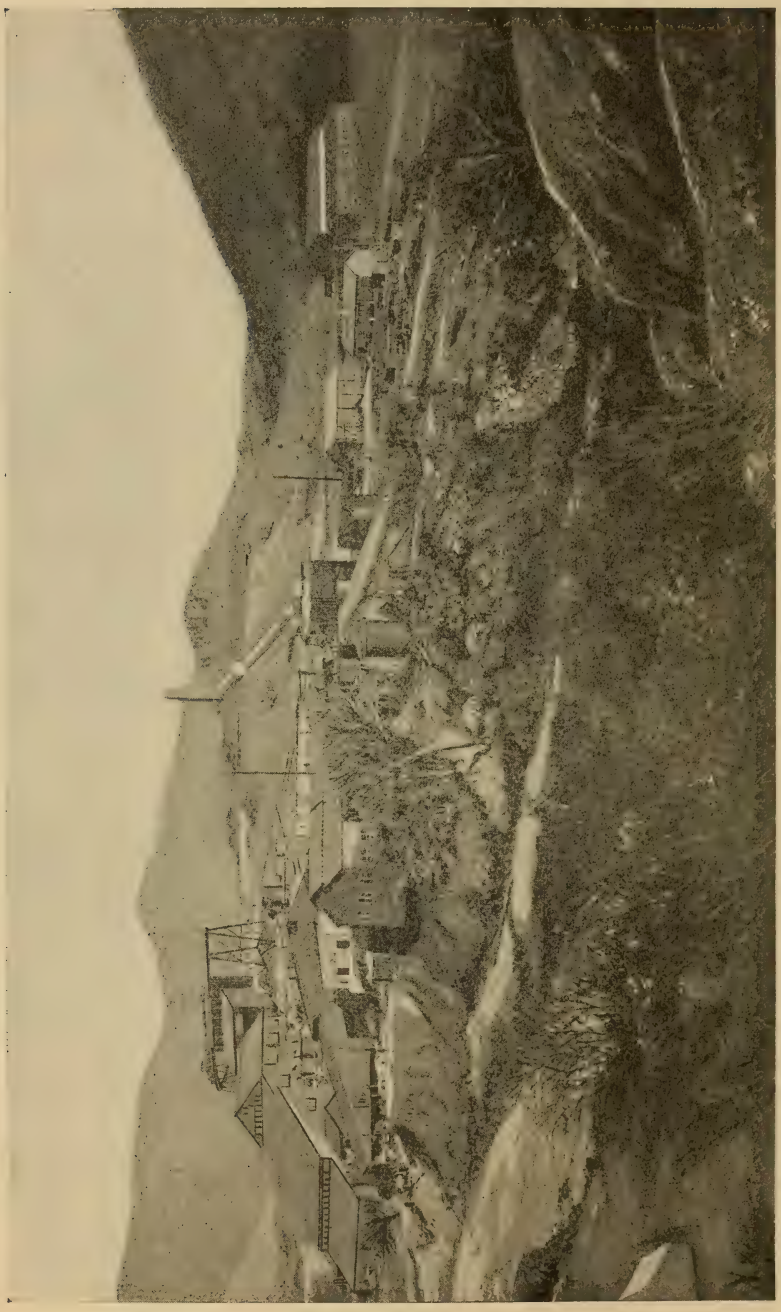
Two qualities of gas are made alternately, as the fires are supplied with steam or air. Two gas holders are, therefore, in use, one having a capacity of 5000 cubic feet, for water gas, and the other a capacity of 15,000 cubic feet, for producer gas. The two gases are mixed in fixed proportion, giving a uniform gas, which is essential in operating gas engines.

With the Loomis system the fuel is charged through an open door in the top of the generator and the gas is exhausted from the bottom of the fire, thus converting all tarry and volatile matter in bituminous coal and wood into a fixed gas, which is then drawn through an ordinary water-spray scrubber by an exhauster and delivered to the holder. Coal is shoveled into the top doors as needed. Wood is charged in lengths of 2 or 3 feet and of ordinary cordwood diameters. The fires are cleaned twice a week. The water for the scrubber is cooled by a simple tower, and is used over and over.

The dynamos are operated by eight gas engines made by Messrs. Crossley Brothers, Ltd., of Manchester, England, rated at 110 horse-power at a speed of 200 revolutions per minute. Four additional engines, rated at 200 horse-power each, are now being installed. Eight tanks contain water for the circulating system for cooling cylinders. Each engine is belted direct to a 65 KW, 260-volt, shunt-wound, direct-current generator, built by the General Electric Company, of New York, with a normal speed of 910 revolutions per minute. The current from the eight generators is carried to a switchboard by overhead cables. This switchboard consists of eight generator panels, one main station panel and one feeder panel. The current is transmitted to the departments through four circuits, each having an area of 500,000 circular mills. Two of the circuits are taken to two distributing boards in the concentrator department, one for each mill, giving a total of 500 horse-power, with an overload capacity of 25 per cent. Another is taken to the furnace and converter

THE DETROIT COPPER MINING COMPANY'S WORKS AT MORENCI, ARIZONA, U. S. A.

The Gas Plant is located between the Smelting and Concentrating Plant, with gas piped three-quarters of a mile from Smelter and one-quarter of a mile to concentrating mill. The Main Power Plant at Smelter consists of two 150-H. P. gas engines, each operating a 120-K. W. alternating Electrical Generator running in parallel. Induction motors are used in this department. The concentrating mill is operated by three 80-H. P. Gas Engines. There are a number of small gas engines of different makes about the works.



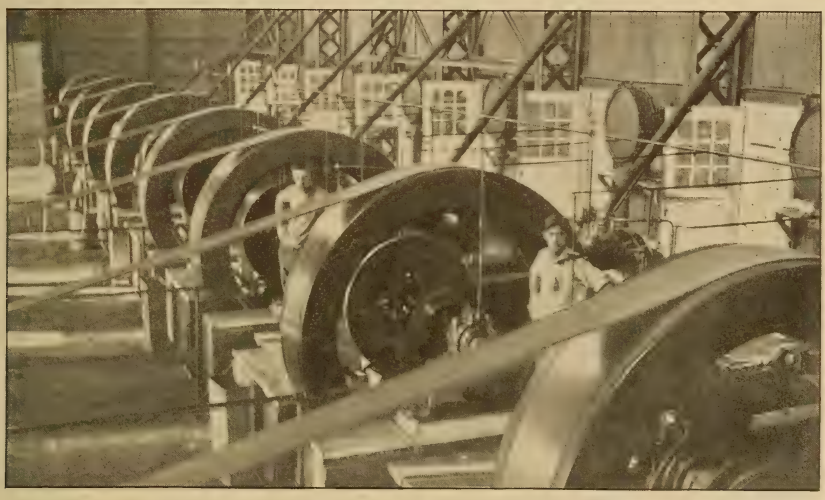
THE CONCENTRATING AND SMELTING PLANT OF THE MOCTEZUMA COPPER CO., NACOSARI, SONORA, MEXICO. ALL THE POWER IS FURNISHED BY LOOMIS GAS PLANT WITH GAS ENGINES AND ELECTRICAL DISTRIBUTION

room for other machinery and lighting. This plant ha sbeen operated for the past year on wood, principally white oak, with a little mesquite. The average load for twenty-four hours is about 500 B. H. P., varying from 300 to 650 B. H. P., and the consumption of wood is three pounds per B. H. P. per hour. With New Mexico bituminous or anthracite coals, 1.5 pounds are used per B. H. P. per hour.

The gas plant of the Detroit Copper Company, Morenci, Ariz., is similar to the one at Nacosari, and is located on mill, operating three 80 H. P. Otto-Crossley engines, belted to countershaft which drives the mill. An equipment of 800 H. P. of gas engines is being added to this plant.

Gas power outfits for mining and smelting plants operate to the best advantage under the following conditions:—When fuel cost is high; when wood, bituminous, or anthracite coal are the fuels; and when water is scarce or of poor quality for steaming purposes.

With plants of 250 H. P. or more under everyday working conditions one

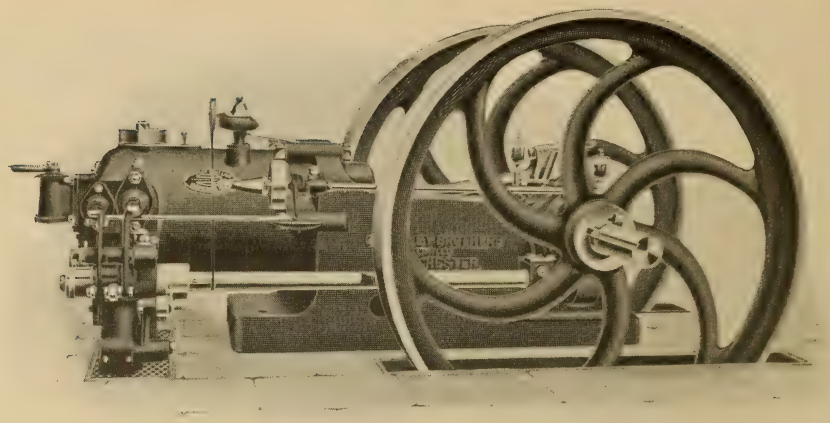


THE POWER HOUSE OF THE MOCTEZUMA COPPER CO., NACOSARI, SONORA, MEXICO, CONTAINING EIGHT 100-H. P. GAS ENGINES RUNNING CONTINUOUSLY 24 HOURS A DAY THROUGHOUT THE YEAR

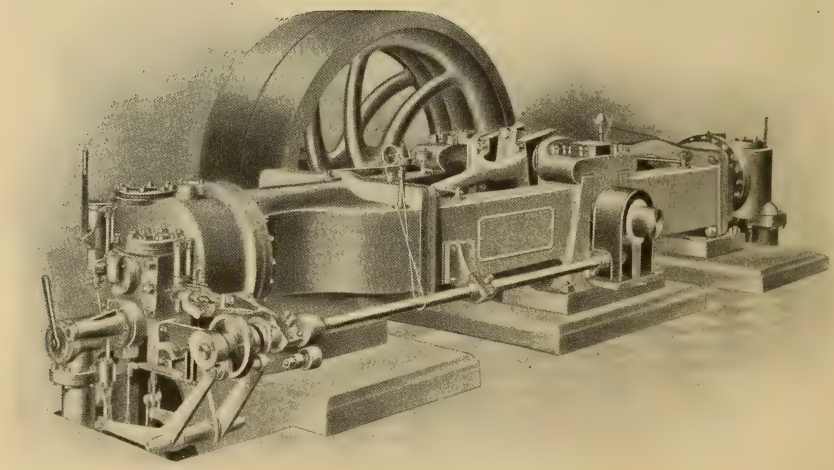
the railroad between the smelter and the concentrating mill. The gas is piped one mile to the smelters, supplying two 200 H. P., three-cylinder, vertical Westinghouse gas engines. Each engine is belted to a 120 KW, alternating-current dynamo. These dynamos work in parallel, supplying current to motors and for lighting. A 60 H. P. Stockport gas engine, made by Messrs. J. E. H. Andrew & Co., Ltd., of Reddish, near Stockport, England, operates conveyors and briquetting machinery, and a 60 H. P. gas engine, made by Messrs. Fairbanks, Morse & Co., of Chicago, runs an air compressor. The gas is piped 2000 feet to the concentrating

brake H. P. per hour is produced with from 1.25 to 1.5 pounds of bituminous or anthracite coal, or with 3 pounds of wood. The consumption of water need not exceed 2 pounds per B. H. P. per hour.

The steam from a good boiler plant represents about 70 per cent. of the heat developed by the combustion of the coal, and as a good steam engine is able to deliver about 14 per cent. of the heat of the steam as power, we have a total efficiency of about 10 per cent. The gas from a power gas plant, on the other hand, contains over 80 per cent. of the heat in the coal, and a gas engine delivers 25 per cent. of this as power,



A RECENT TYPE OF CROSSLEY GAS ENGINE USED BY THE MOCTEZUMA AND THE DETROIT COPPER COMPANIES. MADE BY MESSRS. CROSSLEY BROS., LTD., OPENSHAW, MANCHESTER, ENGLAND



A STOCKPORT GAS ENGINE USED BY THE DETROIT COPPER CO. MADE BY MESSRS. J. E. H. ANDREW & CO., LTD , REDDISH, NEAR STOCKPORT, ENGLAND

making the total efficiency 20 per cent.

The above is a fair comparison of steam and gas mining power plants where the coal consumption for steam is 3 pounds per B. H. P. per hour and for gas 1.5 pounds per B. H. P. per hour. The results mentioned with steam are obtained only with the largest and best mining power plants, the general practice being 4.5 to 8 pounds of coal per B. H. P. per hour. The investment, operating expenses for labour, oil, repairs, and maintenance will be about the same for a gas-power plant as for a first-class steam plant.

The amount of saving effected with a gas installation, by being able to get along with so small a quantity of water, or with water of an inferior quality, cannot be stated definitely, as the conditions vary widely in different localities. The following table shows the fuel sav-

ing per annum (8760 hours) with a gas plant using 1.5 pounds of coal per B. H. P. per hour, as compared with a steam plant using 3 and 4.5 pounds of coal, respectively:—

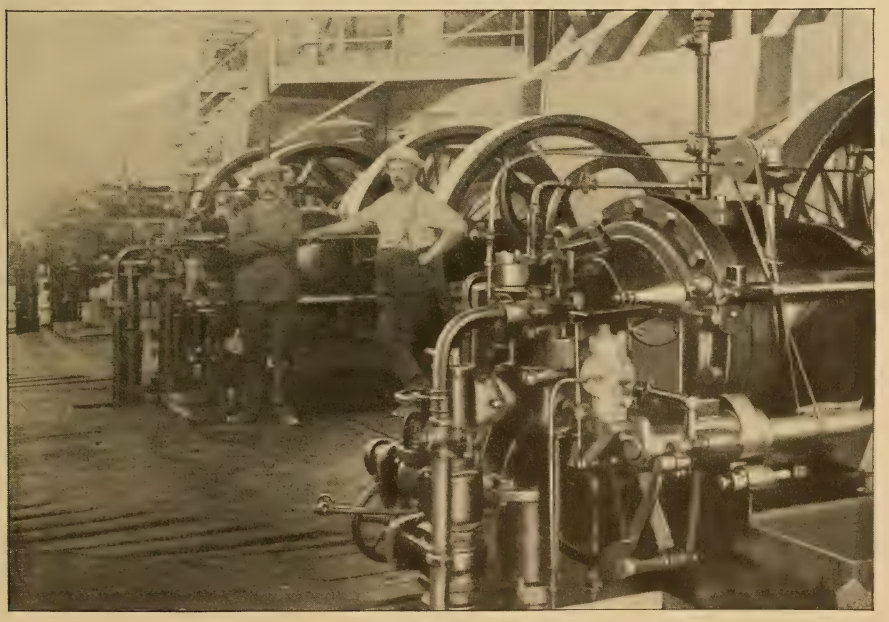
Price of Coal per ton.	Saving per B.H.P. per Annum. Gas Plant 1.5 lbs. Coal. Steam Plant 3 lbs Coal per B. H. P. per hour.	Saving per B. H. P. per Annum. Gas Plant 1.5 lbs. Coal. Steam Plant 4.5 lbs. per B.H.P. per hour.
$2.50	$14.65	$29 30
5.00	29.30	58.60
7.50	43.95	87.90
10.00	58.60	117.20
12.50	73.25	146.50

A gas-power plant using wood for fuel shows the same ratio of saving as with coal, from 2 to 2.25 pounds of wood being equal to 1 pound of coal. The wood is used in 2 or 3-foot lengths and of ordinary cordwood diameters. The heating value per pound of all varieties of wood is about the same, so that the kind of wood need not be considered when the estimates are based on weights.

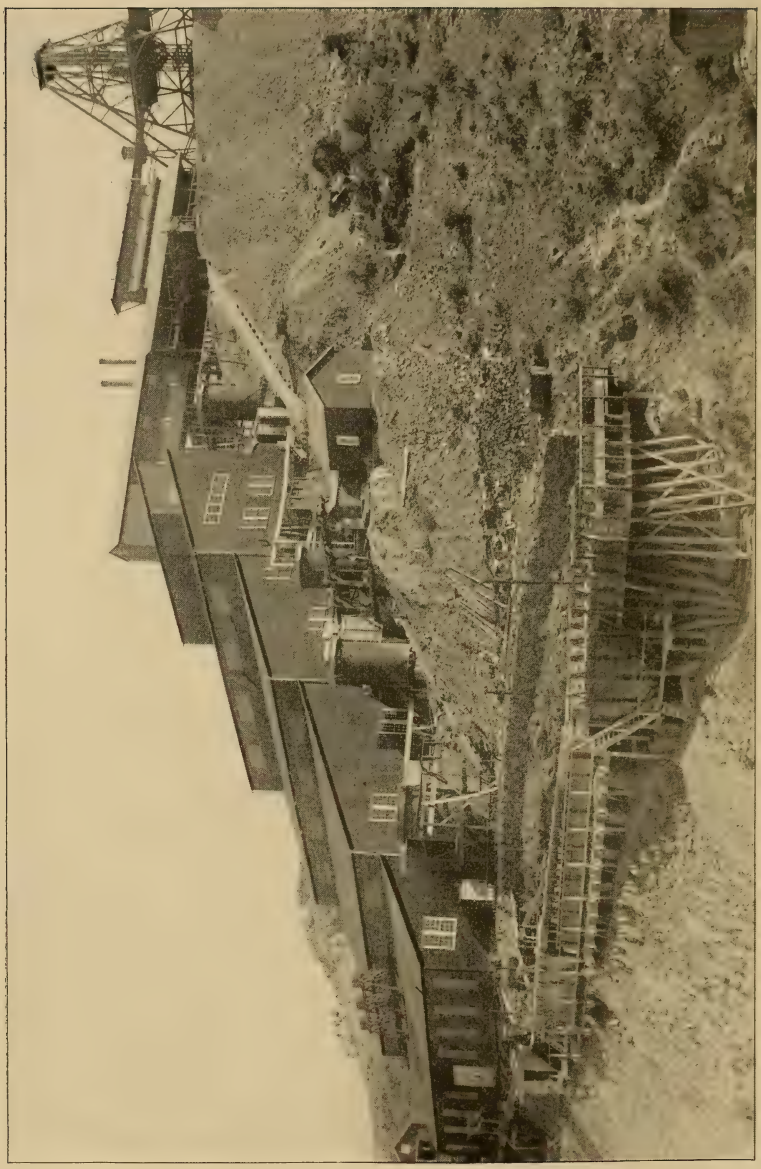
Gas-power plants involve two processes,—first, the conversion of the fuel into gas; and, second, the combustion of the gas in the cylinder of the engine developing the power. The cheapest gas suitable for power that can be furnished is made from coal, either bituminous or anthracite, coke, or wood, by passing air and steam either alternately or together through deep beds of incandescent fuel. The resultant gas is passed through scrubbers, or towers with water sprays, to holders of moderate size. The apparatus is simple, safe, and easily operated.

The gas must be clean, fixed, and of uniform quality. It contains from 125 to 150 British thermal units per cubic foot, and 80 to 100 cubic feet will produce one brake horse-power for one hour in a gas engine. The rate of gas-making is regulated to meet the varying demands for power. The gas being fixed and clean, it can be piped any distance through ordinary iron pipes, and engines can be located where desired. There is no thermal loss in piping the gas, the cost being simply the investment for pipe and the power required to force the gas through the pipe.

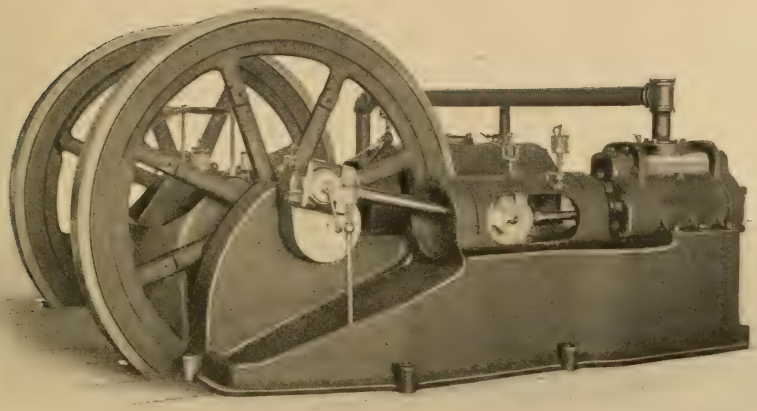
The costs for distribution by gas can be figured on the basis of allowing 80 cubic feet of 150 British thermal unit gas per brake horse-power and using ordinary pipe. In order to reduce the cost



CONCENTRATING MILL OF THE DETROIT COPPER CO., OPERATED BY THREE 80-H. P. GAS ENGINES



THE CONCENTRATING MILL OF THE DETROIT COPPER CO., AT MORENCI, ARIZONA



A 60-H. P. GAS ENGINE AND DIRECT CONNECTED AIR COMPRESSOR MADE BY MESSRS. FAIRBANKS, MORSE & CO., CHICAGO, FOR THE DETROIT COPPER COMPANY

for pipe the gas can be distributed under high pressure.

The following systems have been adopted in applying gas-power plants to mining work:—

Central gas plant convenient to fuel supply with gas piped to gas engines located where power is required. The gas is also used for metallurgical work where desired.

Central gas plant with gas engines and electric generators convenient to fuel supply, and the electric current wired to motors directly applied for power.

A combination of the above, gas engines used for large powers near the gas plant, and electric current distributed for distant powers, outlying mines, etc.

Where there is a community of small mining plants using ordinary steam equipment, a central gas-power plant, supplying them with electric current or gas for power, would effect large savings.

Local conditions govern the system of distribution to be adopted. As moderate-sized gas engines are about equal in price and efficiency to large ones, and as there is no loss in transmitting the gas, a complete gas installation shows the highest efficiency and the lowest cost for installation. A number of gas engines located in different parts of the plant require no more attention than as many electric motors.

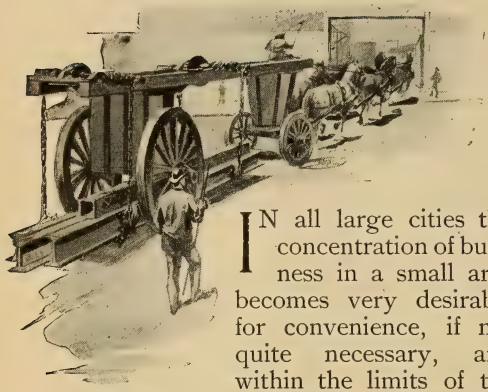
While electrical distribution increases the investment, it shows most excellent results in many cases, and where many changes are made in the processes and the power needed in different parts of the work varies from time to time, all requirements are quickly and easily met. Electric motors have been applied to all classes of mining work and have proved their reliability and efficiency.

Properly installed, a gas-power plant will give as reliable service as a steam plant, and will meet all the demands of everyday working conditions. No more skill is required in its operation than for operating a steam plant, and the same grade of labour can be employed.

THE MODERN TALL STEEL BUILDING

CORROSION AND FIRE DANGERS

By William Sooy Smith



IN all large cities the concentration of business in a small area becomes very desirable for convenience, if not quite necessary, and within the limits of the business districts rents are high and the value of the realty is greatly enhanced by this concentration. As the number of square feet of rental space that can be made available on a given area of the site of a building varies with the number of its stories. it becomes a great object to the owner to build as high as all the circumstances will permit.

As steel is the strongest material used in construction, it has naturally come to the front for use in the skeletons of the so-called American "skyscrapers." But it is not its strength only that entitles it to this preference; there are to be considered the ease and perfection with which all its parts can be accurately proportioned to the strains to which it is to be subjected; its uniformity in quality; its cheapness, tenacity, and lightness; its unequalled capacity to endure shocks, vibrations, and strains varying in direction and intensity; and its durability, when properly used and protected.

These advantages have been learned and are appreciated by engineers, architects, builders, and owners; hence the wonderful increase that has taken place in the use of steel for structural purposes within the last two decades. In this use the interest and safety of the public at large are both deeply involved and well secured if the material is used and taken care of as it should be, in accordance with simple requirements by means well known to competent engineers and architects. With such precautions, the steel building is durable and the safest of all.

Without steel the so-called "skyscraper" would be impracticable from its enormous weight and cost; and in a building of any height and of any materials, neglect of correct plans, execution, and preservation is always dangerous and often fatal.

The term "fireproof" is only relative, for there is scarcely anything that will resist the highest known temperature even if applied for a few hours only, and the best and cheapest materials used in buildings do not belong to this class of refractory substances. The danger from very high temperatures that might be developed by fires may be reduced or prevented by admitting only very small quantities of the more combustible materials, both in the construction of the buildings themselves and in their contents, and by the use of fireproofing coverings for the structural parts.

Even in the construction of small houses a cheap wooden frame can be erected and covered, both inside and out, roof and all, with a first-class fireproof plaster that will stand exposure to weather. Such dwellings can be made cheap, fireproof, warm in winter and cool in summer, will need no painting, and will be practically as durable as brick or stone houses. Larger buildings may be constructed in like manner, and even brick and stone structures may be so

plastered and made fireproof, and be otherwise greatly improved.

The subject of buildings is of vital interest to all mankind. Our convenience, comfort, health and, safety depend largely upon the character of our dwellings and of the buildings in which our labour is done and our business transacted. It is especially requisite that the materials employed and the modes of construction shall be such as to make the building strong, durable, safe, and economical. They should also be as nearly as possible proof against destruction by fire, or by fire and water combined, as they are generally exposed to the joint action of the two in cases of conflagration.

But the "skeleton construction" now so common in the large American cities for tall buildings is about as faulty and objectionable as it can be when exposed to this combined action. The expansion of the steel which the buildings contain is at the rate of a tenth of an inch per foot for a change in temperature of 1000 degrees (red heat). Of the other materials,—stone, brick, terra cotta,—each has its own rate of expansion, differing from one another and from that of steel. They all differ also in their conductivity of heat. Even if these materials and steel are raised in temperature equally throughout their whole length, the increase in length will differ in each material, and taking the conditions as they occur in almost all burnings of buildings, the steel, being a good conductor, will be heated much more quickly and through a much greater part of its length than any of the other materials present. The differences in the total dimensions of the several parts of the building resulting from these causes will be so great as to bring about a destructive war between them. This is not mere theory. It has been practically proven by close observation of the effects of a number of fires.

When a fire is in progress in a building and its parts are heated to a high temperature the fire engines throw powerful streams of cold water on the heated materials, and most of those now commonly employed fly to pieces under the joint action of the fire and water. So say all who have become familiar with the effects of fire and water on building material. This is especially true of the light integument of terra cotta built around the steel columns of a skeleton building.

Iron and steel being the strongest materials used in the construction of buildings, and, in proportion to the service to be performed, two of the cheapest, have deservedly come rapidly into use, particularly in the United States, for the very tall structures that have been erected in the business districts of large cities.

The experience previously gained in the construction of iron and steel bridges throughout the world prepared the way for the use of these metals in buildings, and to some extent developed correct methods of proportioning and connecting their parts. But it seems remarkable, in view of this experience, that such radical defects still creep into the details of iron and steel framing in buildings as the flimsy lug and bracket connection of beams and girders with the columns, the eccentricity of loads on the columns, and the want of provision for expansion and contraction of the parts. These defects are, however, easily remedied.

Supposing, now, that all the metal parts of a building are properly shaped and connected, and all the loads and strains which the skeleton frame is to sustain are amply provided for, two great dangers threatening the safety and durability of the building still remain, viz., the weakening and destruction of the metal members by corrosion or by heat. These dangers are actual and obvious. But the precise rates of weakening by heat and destruction by corrosion under different circumstances are not as accurately known as they should be.

A column of iron or steel, such as those now commonly used in tall buildings, would hold little more than its own weight when red-hot; and it is well known that there is a dangerous weakening effect of heat at much lower temperatures. Tests made at Watertown,

Mass., in 1890, by Mr. James E. Howard, for the writer, led to the following conclusions:—

"The modulus of elasticity of both iron and steel decreased with an increase in temperature, the change being more marked with mild steels.

"The elastic limit, like the modulus of elasticity, decreases with increased temperature, the rate of change being affected somewhat by the amount of carbon in the steel. With an increase in temperature there is a decrease in tensile strength, the latter, in the case of mild steels, reaching a minimum at about 200 degrees F. With a still further increase in temperature there is also an increase in tensile strength, but at about 460 degrees F. the tensile strength reaches a maximum. As the temperature rises above this point the tenacity diminishes rapidly."

Experiments made by R. Luehmann, at Hamburg in 1888, are very instructive, showing that "the breaking load of a wrought-iron column per square inch of cross-section when red-hot is only one-half as great as when the column is cold (normal temperature)."

From this it must be apparent that the usual method of giving to columns, beams, and girders certain loads and proportions, such as to secure ample strength with a proper factor of safety while the metal is at ordinary atmospheric temperature, is altogether insufficient to ensure safety in case of exposure to the high heat that may attack it during a conflagration. And here let it be remembered that the metal while heated loses much of its strength to resist tension and compression, and also loses in greater degree its resistance to lateral flexure, and so the entire skeleton of a building may be deprived of the stiffness necessary to its stability.

It happens, too, that while the columns, beams, and girders are weakened, they are also expanded by heat, and unequally as the degree of heat varies to which the different members are exposed. The unequal expansions of the horizontal beams and girders push the columns out of vertical into buckling positions, rendering a collapse of the whole structure almost certain. This has occurred in many instances, and is likely to occur whenever fire attacks a skeleton building in which the metal parts are not absolutely protected by proper fireproofing. It also frequently happens that the horizontal expansions of the beams and girders crack and shove out the walls against which their ends abut.

Many buildings having skeletons of iron and steel imperfectly protected by so-called fireproofing, have failed when heated by fire either in these buildings themselves or in some instances from the burning of an adjacent building, even at a considerable distance away, notably in the case of the Manhattan Savings Bank building, in the city of New York, which was ignited by the burning of another building 40 feet away, and practically destroyed, and also in the cases of three steel skeleton (so-called) fireproof buildings ruined by fire in Pittsburgh in 1897. The story of this fire was, at the time, summed up in a few lines in the *Engineering News*, as follows:—

"A fire starts in an old type of brick and wood, slow-combustion building filled with highly inflammable material, and before its progress can be checked it sweeps over an area of nearly two city squares, destroying property to the amount of $3,000,000. Within this area, besides the first-mentioned buildings, there were three modern fireproofed, steel skeleton buildings and half a dozen small shops and dwellings of ordinary brick and wood construction. When the flames had completed their work, there remained of two of the fireproof structures only the outer walls and shattered floor arches, held together by the steel frame; the third fireproof building had five of its light floors swept nearly clean of their contents and their dividing walls and partitions injured beyond repair, and the brick and wood shops and dwellings were simply heaps of masonry."

This brief description clearly established the fact that the three "fireproofed, steel skeleton buildings" were not fireproof, and, indeed, it turned out

that in one of them 50 per cent. of the columns were found, after the fire, stripped of their covering.

The rate of corrosion of iron and steel varies greatly under different circumstances. In pure water, containing no free air, with an air-tight covering of paint, or imbedded in quicklime, it scarcely corrodes at all; but when in the open air, particularly when alternately wet and dry, it rusts quite rapidly, and when exposed to steam and sulphurous fumes it is eaten away by corrosion at the rate of one-eighteenth of an inch per annum, as was the case in the floor system of a viaduct in Chicago under which locomotives were passing frequently. Corrosion at the same rate occurred in a portion of the western approach of the Eads Bridge at St. Louis, where the same conditions exist. As the metal in a steel column is usually not more than half an inch thick, corrosion at the above rate would make a steel building unsafe in less than twenty years.

In an iron or steel skeleton building the columns, starting at the basement floor, or at the floor at street level, extend to the top of the building. They are hollow and are painted only on the outside, and this with paint so perishable that it will afford no protection from corrosion after the first five or ten years. The girders are nearly as much exposed as the columns, while the beams are generally bare on the top and bottom surfaces of the flanges, and sometimes over a considerable part of the webs.

Wherever the surfaces inside or outside are left uncovered, they are exposed to corrosion that will be more or less rapid, according to the temperature and hygrometric conditions of the air surrounding them. In many instances, particularly in factories, there are destructive elements in the atmosphere, such as sulphur and chlorine, which may cause rapid wasting away of the metal, and these elements are the more dangerous, as they are apt to escape notice while destroying parts that are concealed.

Corrosion may be prevented by covering all metallic surfaces, both inside and outside, with an indestructible anti-corrosive coating. This having been done, all the metal parts must be enclosed in a fireproof and fireproofing material that will not only resist the heat of a conflagration, but so shield the metal from an attack by heat as to prevent any considerable changes of its temperature, and this may be best and most certainly accomplished by having an eye to the fireproofing of each individual structural member.

Slow combustion of buildings can be secured by carefully whitewashing the inside and outside with fireproof material laid on with a brush. Fire departments claim that they can extinguish almost any fire if only it is prevented from spreading too much before they can bring their engines into play.

It is of the utmost advantage to protect each building from the danger of taking fire in case of the burning of its neighbours, and this can be at least measurably done by the whitewashing suggested, particularly of the roof, and by putting fireproof shutters on all windows and openings of every kind. Where there is an open court in a building, some sort of fireproof covering should be put on all parts of such court, and the same protection should be given to stairways and elevator shafts.

The essential characteristics of a fireproofing material for buildings are:—

1st.—It must itself be incombustible.

2d.—It must be as nearly as possible a non-conductor of heat.

3d.—It must be strong and durable.

4th.—It must endure heating to redness and plunging into cold water without cracking.

While there are very many so-called fireproofing materials in use for which these qualities are claimed, there was, up to a very recent period, not one of them that was a good non-conductor of heat, and that would stand heating to redness and being plunged into cold water while red-hot without flying to pieces.

The requirements of a building are that it shall be strong enough to carry all its loads and resist wind pressure and all other strains to which it may be sub-

jected as a whole or in any of its parts, and that it shall be durable and not unreasonably costly.

Supposing that steel is used for the framework of the structure, as being preferable to any other material, and that proper shapes and sizes of all parts of such frames have been carefully and correctly determined and the disposition and connections of these parts have been properly made, it only remains to provide the skeleton of the building, inside and outside, roof included, with a covering that shall be fireproof, strong, and durable, and, if possible, light, tough, and elastic, a good non-conductor of heat, and impervious to air or water. Such covering can be made of fireproof plaster of any necessary or desirable thickness, and suitable cornices and mouldings can be worked out of the same material.

The great weight of tile, brick, and stone now used would thus be dispensed with and the much lighter construction described substituted. A very great saving of weight in the frame itself would be effected, and the cost of the necessary foundations of the building would be greatly reduced. Still other important advantages would be secured which need not be mentioned here. Enough has been said to invite the careful and unprejudiced study and criticism of engineers and architects, and out of this kind of investigation there may come a new system of building that may be the ideal one of the future.

The highly inflammable buildings now erected and occupied are a disgrace to the high civilisation of our age and in flagrant violation of all the well-established facts and dictates of the advanced art and science which are its distinguishing characteristics.

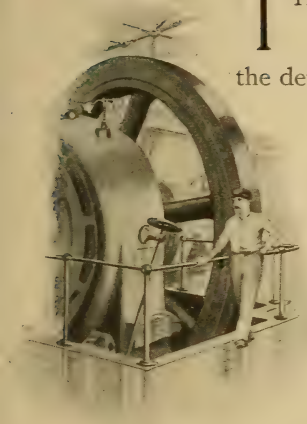
How can we better serve our day and generation than by energetic and persistent efforts to correct the great evils that exist? And in the physical world, what are the conditions, capable of being corrected, that result in the fearful destruction of life and property periodically recurring?

When a dozen or two, or even a hundred people, unable to escape from a burning building, or a number of firemen, battling with the flames, are burned to death, we read a notice of the deplorable event in the daily newspapers, exclaim, "It is horrible!" or "It's too bad!" and pass on to other news, thinking little more of it. From their very frequency these disasters cease to make a lasting impression.

While such wonderful progress has been made during the latter half of the nineteenth century in the development and applications of physical science, it seems passing strange that so little has been done to mitigate these evils. What we need are tests and investigations by the best experts in the world to ascertain practical and efficient means of making thoroughly rustproof and fireproof buildings.

ALTERNATING CURRENT ENGINEERING

By B. A. Behrend, C. E., E. E.



THE last decade of the nineteenth century was conspicuous for the development of electrical engineering in general, but its most distinctive feature was unquestionably the growth and evolution of the alternating current, and, consequent upon it, the calling into life of a new and large industry employing thousands of men and women, and adding materially to the comforts and commodities of existence, by which, in last analysis, we measure the worth of our labour. But in this age of eulogy upon the material fruits of the engineering industries,—to most men the be-all and end-all of their work,—it is often forgotten how large a debt industry owes to science, and that the former is only now paying back the loan which it has received during the past century from the noblest and greatest minds of the world.

Since Faraday laid the foundation stone upon which the electrical industry has been reared as a mighty superstructure, since Clerk Maxwell, Kelvin, Helmholtz, and Hertz, and a host of great physicists now living, purified the great thoughts of that prince of investigators and discoverers, electrical engineers have had a few guide-posts on their toilsome path. When, fifteen years ago, the first modest attempts at power transmission were made, the engineering public at large was profoundly ignorant of the laws of electricity and magnetism, and only a few masters in science and

FIG. 1.—THE POWER HOUSE AT HOCHFELDEN, SWITZERLAND, 1891

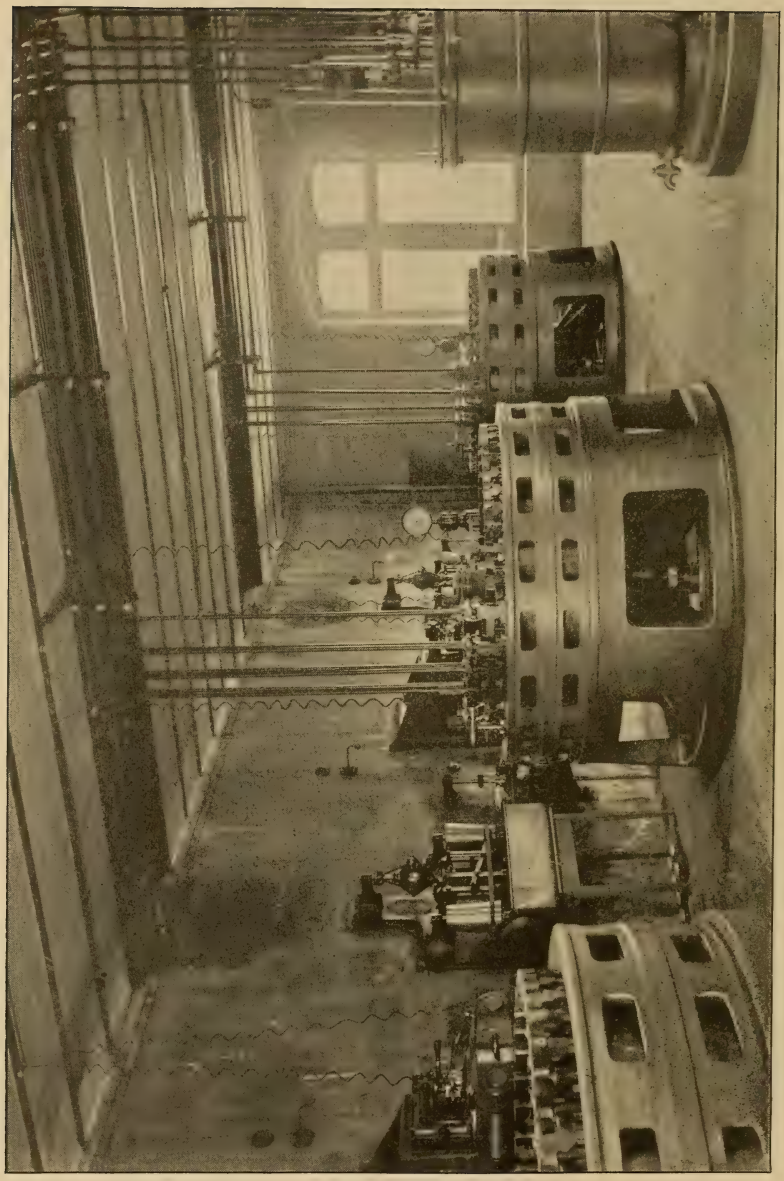


FIG. 2.—THE HOCHFELDEN THREE-PHASE GENERATORS

engineering had some knowledge of the principles that lie at the foundation of successful design for continuous-current machinery. The realm of alternating currents was enveloped in a veil which only a few dared to lift. The dynamo-electric machine had been invented; it was improved upon by skillful mechanics, and while the alternator existed only in the laboratory, lighting and railway generators began to attract the attention of the people. Upon some men, endowed with that divine faculty of imagination which peers into the dark and dim future, the importance of alternating currents for industrial applications must have dawned long before actual facts justified such hopes.

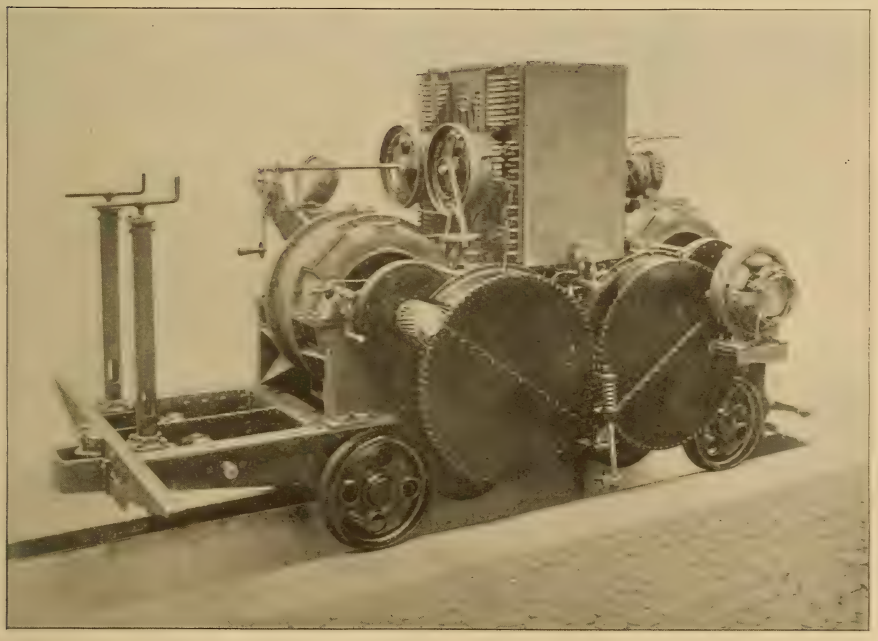


FIG. 3.—THE THREE-PHASE OERLIKON LOCOMOTIVE ON THE JUNGFRAU RAILWAY

Among the great engineers active in the development of the art of electrical industry stand out some men in that remarkable little republic, Switzerland, most attractive by its majestic scenery and its gigantic, white, snow-clad mountains. A very small country, made rich by the influx of strangers from all parts of the compass to admire the natural scenery, Switzerland has achieved engineering fame equal to, and in some measure greater than, that of its powerful neighbours, proving that bigness is not grandeur and that territory does not make a nation. Abundant water-power, with many hotels that desire to give the stranger all the comforts of home, the country readily prompts the utilisation of the waterfalls for giving hotels and dwelling houses the convenience of electric light. Thus the natural conditions of the country stirred the faculties of an intelligent, enterprising and hardy people into activity, leading to the development of a system of electric power transmission that is most remarkable for its flexibility and most conspicuous for its ingenuity.

It is eleven years ago that in the Oerlikon Tool & Engine Works, at Winterthur, Switzerland, a small induction motor for experimental purposes concentrated upon itself the attention of some prominent engineers, among whom were Michael von Dolivo-Dobrowolsky and Charles E. L. Brown. If, in im-

agination, we transported ourselves back into the stage of development of alternating current engineering at that time, we would find that even the most advanced engineers had little idea of the intricacy and complexity of the phenomena upon which they so audaciously entered, and, perhaps, even less knowledge of the phenomena themselves.

There is surely much truth in Darwin's words that "it is often ignorance, and not knowledge, that begets confidence." Thus the fortress of the alternating current was confidently attacked, unheeding the many pitfalls, such as "power factors," "wattless currents," "resonance effects," and a string of other peculiar phenomena that surrounded it, as trenches surround a fort. As a matter of fact, much has been done, theoretically, especially by British physicists, to clear the ground, as far as theory is concerned.

Most alternating current phenomena, being explained by reducing them to the laws of dynamics, have their analogy in the theory of sound, and this theory had been elaborated by such masters as Helmholtz and Lord Raleigh. But these theories, developed, as they were, by men of rare mathematical genius, were almost wholly inaccessible to ordinary minds, on account of the familiarity that they premised with mathematical methods of the greatest complexity. We are safe in saying that, theoretically, everything had been done, and any alternating current phenomenon could have been explained on the principles that were known to the leading physicists; but this knowledge had not yet spread abroad among the engineering world at large. It required what might be called a popularisation of these theories to make them palatable to the builders and designers of plants, and the bulk of this by no means easy work was done by such men as John Hopkinson and Gisbert Kapp. In their papers we find the laws of magnetism clearly and accurately stated and applied; the method of predetermining the saturation curves of generators we owe to them; the theories of parallel running of alternators and of synchronous motors, so important to successful large central station work; the explanation of the "resonance effects," as observed on a large scale on Ferranti's 10,000-volt cables between Deptford and London, based upon the action of capacity and self-induction in alternating current circuits; all these intricate phenomena, and many more, were shown to yield to elementary applications of vector-analysis. And while the acoustic phenomena and their ex-

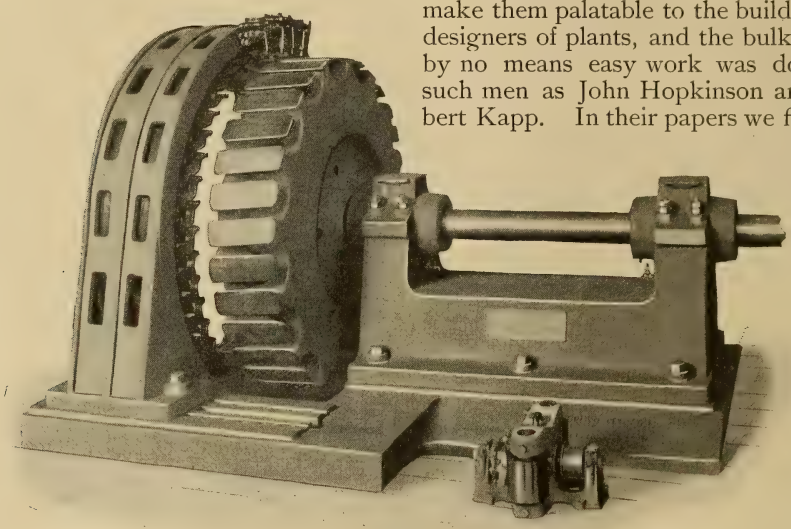


FIG. 4.—A 300-H. P. LAUFFEN GENERATOR, SHOWING THE REVOLVING FIELD

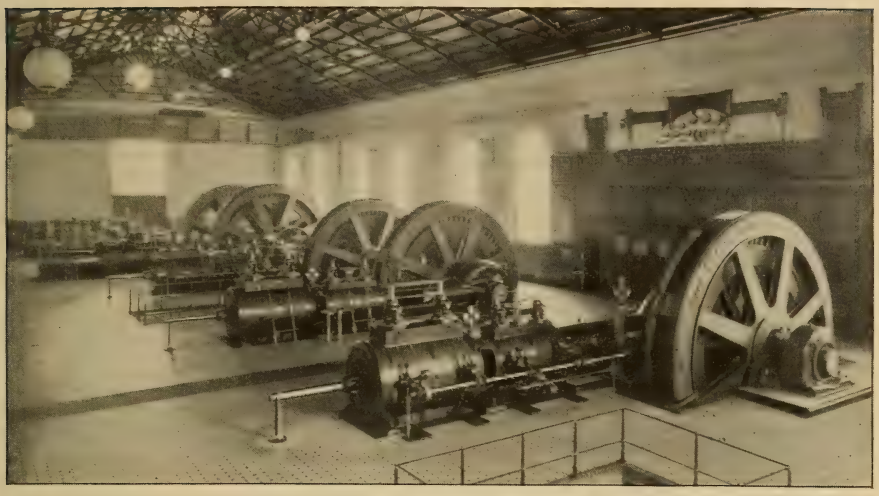


FIG. 5.—SINGLE-PHASE GENERATORS IN THE FRANKFORT STATION

planations received comparatively little attention, the interest in alternating currents was greatly stimulated through the surprising success that was met with in polyphase power transmission.

The integral parts of electric power transmission plants are the generating station, the transformers and the line, and the motors. The writer shall, in this contribution, deal mainly with the generators and motors, because, on the one hand, they are the most interesting part of the subject, and, on the other, they have not been treated in engineering literature with special reference to those details of construction that have made them practicable and successful for the hard service to which they are exposed.

From an historic standpoint, a little plant at Hochfelden, in Switzerland, transmitting 900 H. P. over a distance of 18 miles at 15,000 volts is not without some interest to-day. The well-known experiment of transmitting power at 30,000 volts over 110 miles, between Lauffen and Frankfort, in Germany, had been made in 1891 on the occasion of the Frankfort Electrical Exhibition. The generators, both for the Frankfort experiment and for the primary station at Hochfelden for the transmission to Oerlikon, were of the type that is now known to electricians as the "Lauffen type," the design of C. E. L. Brown. Fig. 2 gives a good view of the 300-H. P., low-voltage generators, with vertical axes keyed direct to the shafts of the turbines.

The exciter dynamos have vertical shafts, and are of the Manchester type, which the late John Hopkinson had introduced, and which were made use of by Brown in 1886 for the transmission of 50 H. P. at 2000 volts over a distance of five miles, between Kriegstetten and Solothurn, in Western Switzerland, at a time when electric power transmission was looked upon rather as an oddity than anything else. The line was supported on Johnson & Phillips fluid insulators, and this little plant is still in operation, as are many other transmission plants with series-wound machines, though their commutators often show rather fantastic shapes, being worn out through a dozen years of toil. The exciting current is led into the revolving field through two slide rings, which run in bare copper wires as a pulley does in a belt. These wires take the place of brushes. In Fig. 1 a view is given of the little power house on account of its historic interest.

The characteristic feature of these machines is the revolving part which forms the magnetic field. A very good illustration of such a field is shown in Fig.

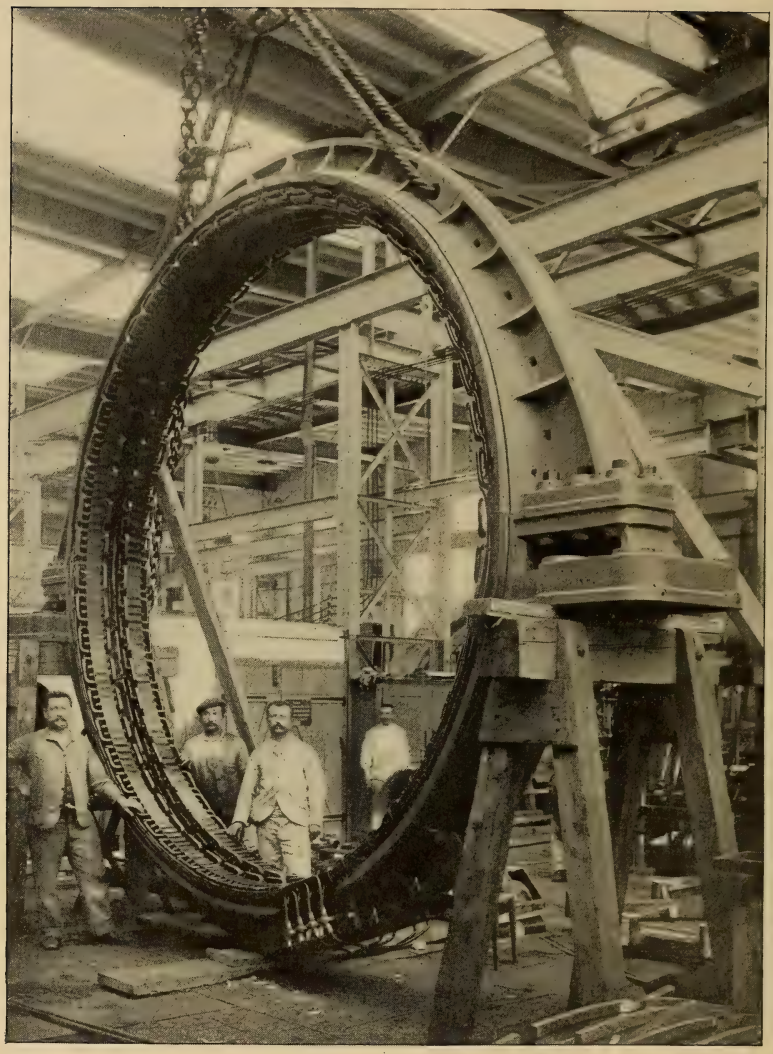


FIG. 6.—THE ARMATURE OF A 500-H. P. OERLIKON INDUCTOR GENERATOR

4, which represents the 300-H. P. three-phase generator used for the transmission of power from Lauffen to Frankfort in 1891. W. M. Mordey's single-coil machine had the great disadvantage that the armature coils projected radially into the field, and slight displacements of the latter were apt to injure the coils through contact with the revolving field. Brown sought to combine the advantage of the single exciting coil with a substantial cylindrical armature, and he devised the ingenious construction of the staggered, overlapping poles, all excited by one circular coil, visible in the crescent-shaped openings of the magnet wheel.

With all deference to the ingenuity of this design, the fact cannot be denied that the Lauffen field is most unfavourable for machines that have to supply current for induction motors. It is well known that the voltage of a generator is reduced materially if a load is thrown upon it. This reduction of the pressure at the terminals is called the "drop" of the machine. It is a

FIG. 7.—THE INDUCTOR OF THE OERLIKON GENERATOR

peculiarity of the alternating current that the demagnetising effect of a current feeding an induction motor is greater than that of a current feeding incandescent lamps. It can be shown that condensers and over-excited synchronous motors have the opposite effect on the field of the generator, viz., they strengthen it, from which follows the interesting and important fact that their action neutralises the "lagging" currents of induction motors. These are the general facts about "armature reaction,"—that most important question in the design of alternators.

The Lauffen type is most sensitive in respect to armature reaction. A generator of this type does not keep the volts at the terminals approximately constant when the load is increased. The machine might be compared with a boiler made of a porous substance, or having seams which leak, losing the pressure whenever it is most needed. Such a boiler would be of little use, and so is a generator having similar prop-

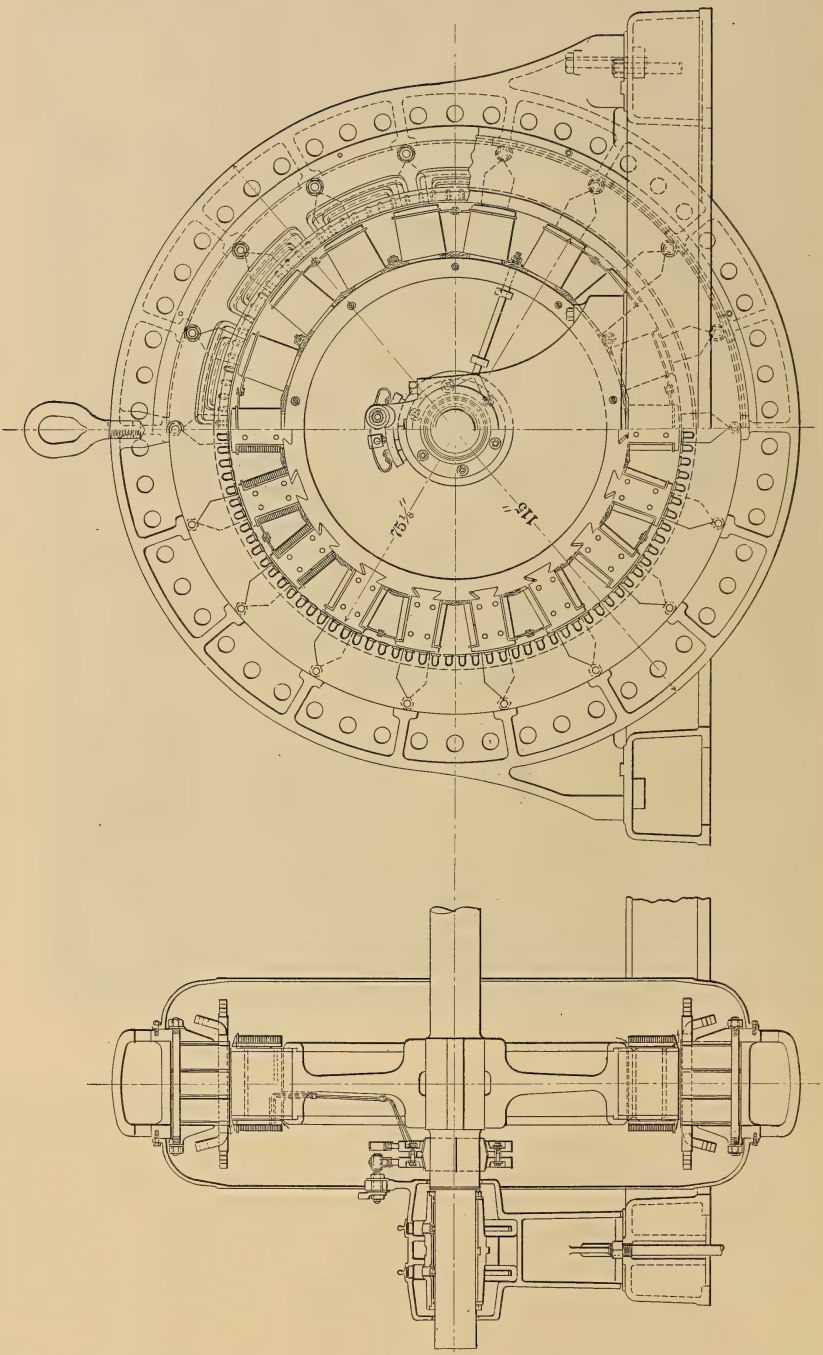


FIG. 8.—SECTION AND ELEVATION OF A 600-K. W. THREE-PHASE BULLOCK GENERATOR

erties. We now know that the field of the Lauffen type has an immense leakage. Brown soon became alive to this inherent defect of his machine and he discontinued building it, while his followers, with the imitativeness of our species and with that inertia characterising the human mind, did not even understand its seeming advantages until Brown had long discarded the construction.

The tendency of the early nineties was toward the external pole type which had done such excellent service in direct current work, and revolving armatures for alternating currents, single-phase and polyphase, sprang into existence. The generation of high voltages in the machine itself led, however, to the stationary armature, as it is not feasible to have armature coils carrying 5000, 10,000 or even 15,000 volts revolving at a speed of 6000 feet or more per minute. A bold English engineer, a most ingenious designer, Sebastian Ziani di Ferranti, had devised his well-known alternator, the coils of which were fastened through insulating material to the rim of the fly-wheel of the steam engine. The field magnets were arranged on each side of the flat coils, and caps of ebonite were slipped over the pole tips to prevent flashing over from the revolving armature to the field. But though these machines, some of which are still in operation in the Deptford central station in London, were examples of the boldness of their designer, they were, mechanically, altogether too unsubstantial.

By the year 1893 the revolving field type had been adopted by Ganz & Co., of Buda-Pest; but they had not succeeded in making machines that could hold the pressure approximately constant with a motor load. Their armatures contained immense quantities of copper, lodged in abnormally large slots, having great self-induction and producing tremendous armature reactions. Their poles stood close together, and the air gaps between armature and field were large, so that a considerable part of the magnetic flux passed from pole to pole without going through the armature coils. These are the conditions that favour the phenomena of "leakage," so injurious in generators

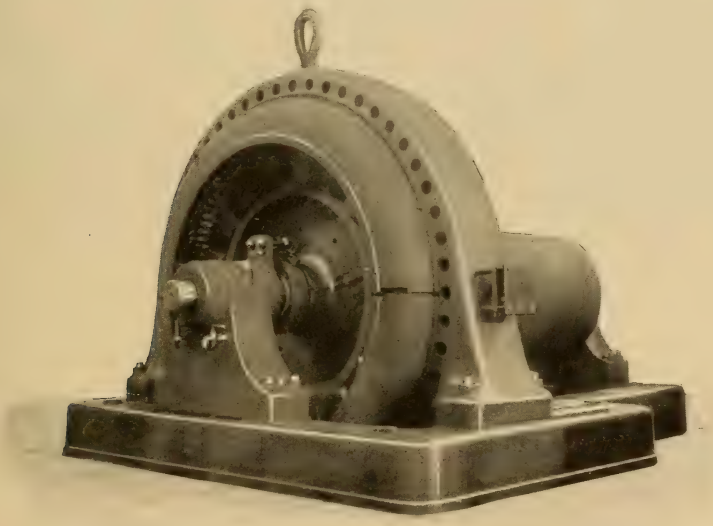


FIG. 9.—A 600-K. W. BULLOCK GENERATOR

intended for good regulation. It required more thought and ingenuity than those who design alternating current machinery to-day can imagine to clearly see the causes of poor regulation.

The Frankfort Electrical Exhibition in 1891 greatly influenced the development of alternating current machinery. The city of Frankfort required an electric central station for 3000 H. P. for the first installation, and the distribution of power and light over a large area in the city was earnestly taken into consideration. The large German electrical factories were not in a position to safely advocate any other than the direct current system. Indeed, it may truly be said that Mr. C. E. L. Brown alone had clearly conceived the possibility and practicability of an alternating current installation to suit these conditions. The writer wishes to cite here the reference to Mr. Brown that the city engineer of Frankfort, Mr. W. H. Lindley, a man of no little reputation himself, addressed to the City Council, as they very well reflect the state of affairs at that time.

"In the place of a batch of engineers, whose ignorance must be acknowledged," said Lindley, "we have before us one of the most talented engineers in the field of electrical engineering, whose constructions show the able hand of an ingenious designer." Those who have been actively engaged during the past six or eight years in the design of alternating current machinery, and have themselves become capable of appreciating a good design, will acknowledge the truth of Lindley's words at that time.

Fig. 5 gives a general view of the Frankfort station, showing in the foreground three of the four 750-H. P., single-phase, 3000-volt units running at 85 revolutions per minute and 45.3 cycles. At the rear may be seen two of the four 1500-H. P. units running at the same speed as the smaller units. At present there are running on the Frankfort mains 5000 H. P. in single-phase induction motors, the largest installation of its kind in the world. A most interesting feature of this station is that not only the alternators run in synchronism, but that the cranks of the tandem steam engines are also synchronised. In this way the non-uniformities in speed during one revolution, inevitable in steam engines, are simultaneous in all machines running in parallel, and thus the "surging" or "pumping," extremely troublesome to the station engineer, is almost entirely done away with. This parallel running of the cranks could be obtained only by having the same number of revolutions for both the small and the large units.

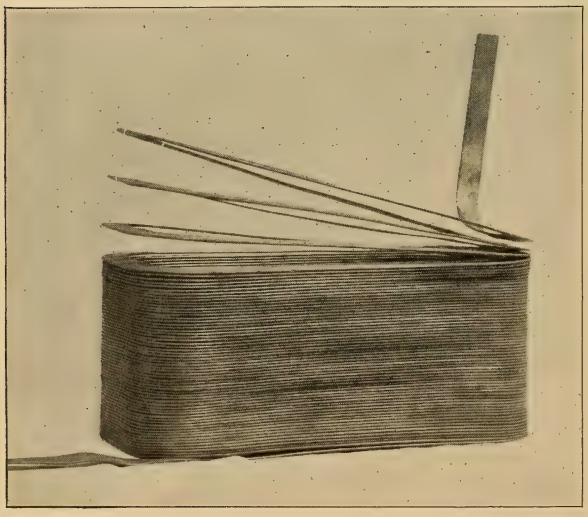


FIG 10.—A FIELD COIL WOUND ON EDGE

The construction of the armature with the eight-arm shields is intended for strength and rigidity. With small air gaps and large diameters, the armature frames have to be made very heavy, unless the construction here adopted is employed. The armatures can be revolved so that repairs can easily be made on any part of the machine; this, added to the other advantage of getting a lighter machine, seems to turn the balance in favour of the shield system.

The armature winding,

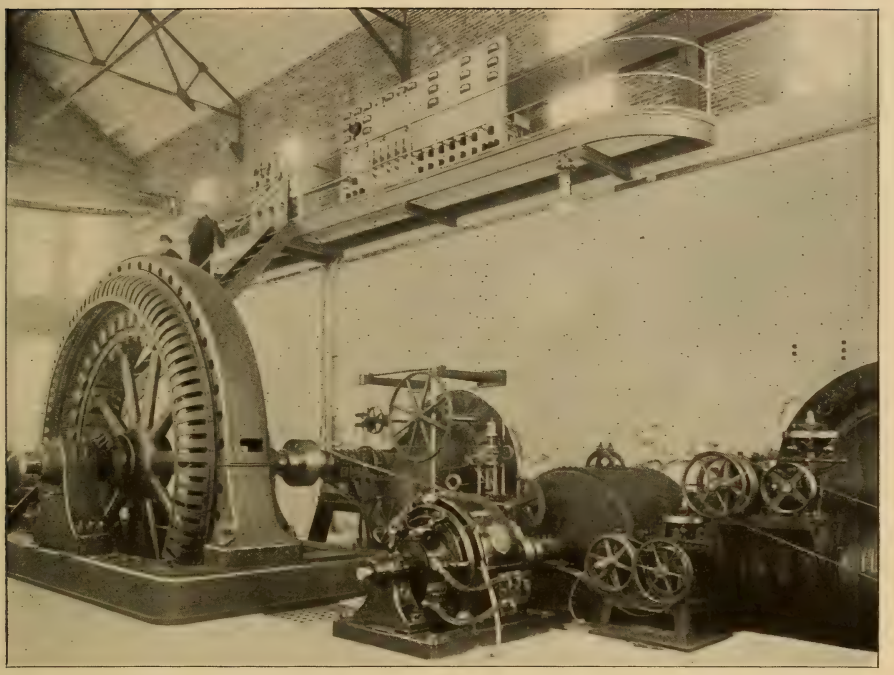


FIG. 11.—A 1000-K.W. THREE-PHASE BULLOCK GENERATOR

consisting of heavy rectangular cable, is lodged in closed slots. This permits the use of solid poles for the revolving field, which again contribute to steady parallel operation by the eddy currents that are induced in them if the angular velocity of the fields is subject to rapid changes. The solid pole effects the same that brass pieces, wedged between the poles and forming bridges between them, are doing, a construction generally identified with the names of the French physicists, Hutin and Leblanc.

The most remarkable feature, in the writer's opinion, is the peculiar winding of the field magnets that Brown introduced. The magnetising coils of the field are made of copper strip wound on edge. It is obvious, in the first place, that this manner of winding permits as high peripheral speeds as are permissible for steel wheels without windings. In the second place, the heat developed in the wires of an ordinary bobbin near the inside has to travel through the insulation, which offers a considerable resistance to the conduction of heat. In the coil wound on edge the heat is conducted to the surface of the coil through the well-conducting copper, and from there it is radiated out into space.

It may safely be said that it was this construction of the field winding that made the revolving-pole type an engineering success. The old way of winding required much more room between the poles than is actually available in most machines. The field coil wound on edge can carry, as is obvious from the above explanations, much heavier currents than a wire-wound coil of the same section, and that it is most reliable and substantial appears also from the fact that we find it to-day adopted by almost all engineers who build revolving field machines. The round steel pole, encircled by the coil, offers with the shortest circumference the greatest section to the lines of induction, diminishing the total length of copper on the fields, and thereby the energy necessary for the excitation. It may be of some interest to note here that Brown proposed this winding in 1892 to Turrettini

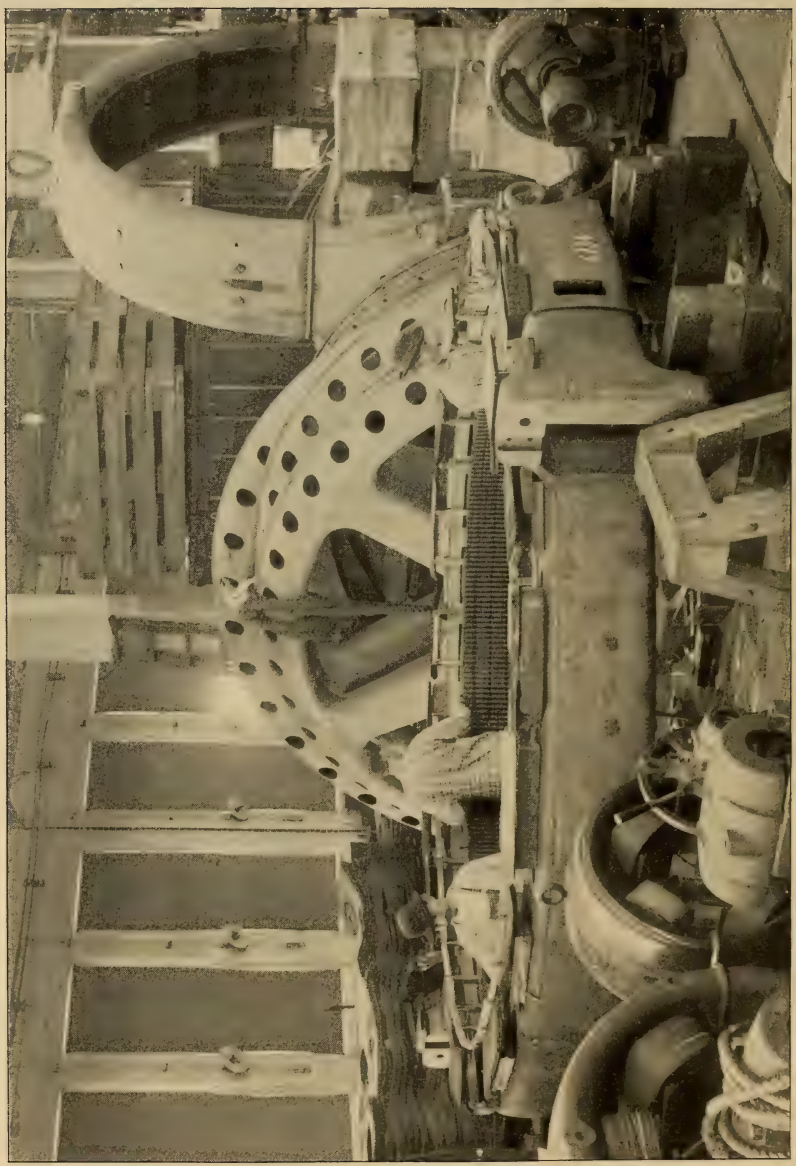


FIG. 12.—ASSEMBLING THE ARMATURE OF A 1000-K. W. GENERATOR

for the large Niagara generators. The poles are bolted on to the U-shaped rim of the fly-wheel. The frequency of 45.3 requires 64 poles, a number that can still be well arranged on the rim of the fly-wheel. At the time the Frankfort station was built it was argued, as it still is, that a frequency between 40 and 50 cycles is unfavourable for large single-phase installations, and that a higher frequency should have been adopted. That the best frequency of plants supplying power and light together is actually between 40 and 50 cycles per second is, however, beginning to be conceded even by former advocates of higher frequencies. As a matter of fact, if the inductive drop is considered a basis of construction, as it justly should be if motors are to be supplied with current, then the higher core losses connected with low frequencies are more than balanced by the diminished inductive drop. Incandescent lighting is perfectly feasible and satisfactory between 40 and 50 cycles, and so is arc lighting, but generators and motors are much more satisfactory and less costly for frequencies between 40 and 50 cycles than at 60 cycles or more. The author visited the Frankfort station several years ago, and he must acknowledge that, were these machines to be built today, they could hardly be improved upon, and he is aware that the same may be said of very few electrical designs turned out six or seven years ago.

The Oerlikon Works after giving up the Lauffen type, developed the inductor generator invented by Mordey and Stanley. One of their most interesting machines is represented in Figs. 6 and 7. The machine is running in Boleo, Mexico. It is a large 500-H. P.

FIG. 13.—A 100-K. W. GENERATOR, WITH DIRECT-CONNECTED EXCITER

inductor generator, producing 5200 volts and 42 cycles at 84 revolutions. It has a bore of 16 feet, the inductor serving as fly-wheel. The armature coils are laid into open slots and are easily exchangeable. Between the two armatures, clearly visible in Fig. 6, lies the large circular exciting coil. It is made of copper band wound flat upon a T-shaped ring of brass.

The winding of this large generator is three-phase. The stationary armature frame is made of cast iron, the armature being built up of sheet-steel. A strong rib is intended to give stiffness to the frame. It is extremely important in inductor generators having small air gaps and high magnetic densities in them to

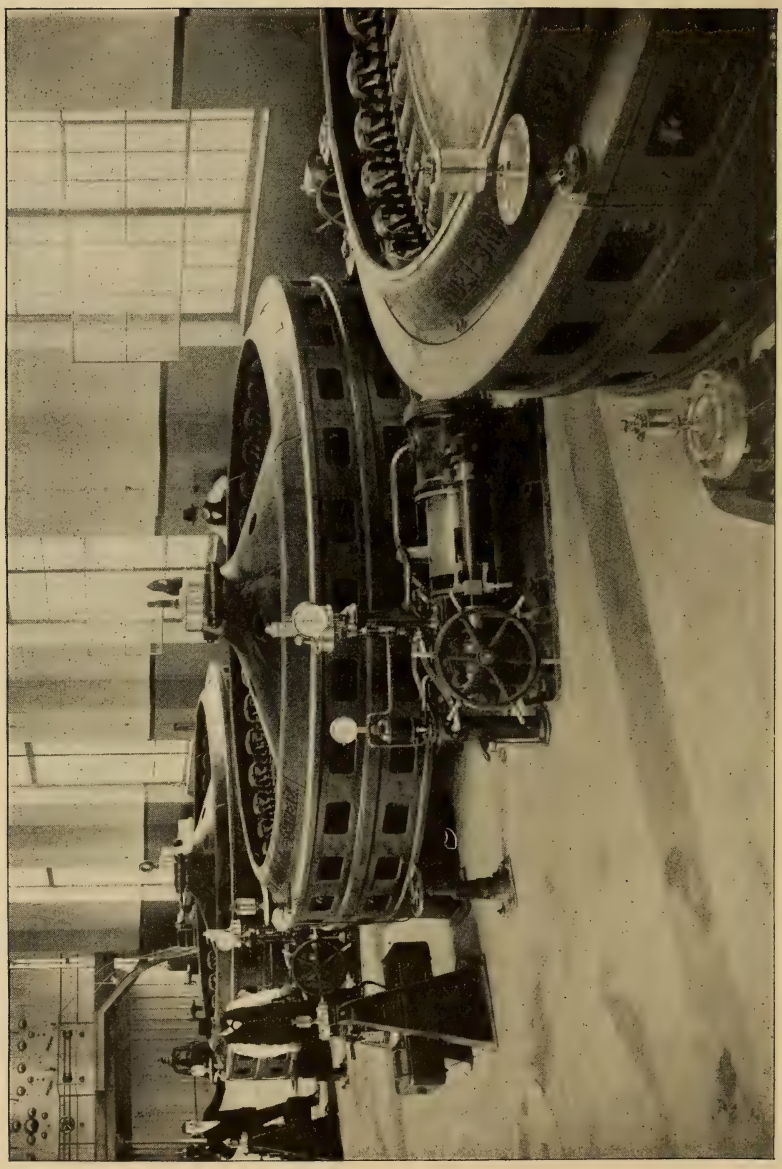


FIG. 14.—BROWN'S UMBRELLA TYPE GENERATORS AT HAGENECK, SWITZERLAND

have a rigid frame, because of the distorting influence on the frame by unbalanced magnetic pulls which in such large machines are hardly avoidable. The inductor in Fig. 7 has thirty projections or pole horns. Since the flux between two such horns must be kept small, as it induces in the armature an electromotive force opposite to that which we want to have, the clearance between "rotor" and "stator" has to be kept very small. The air gap in this machine is only ¼ inch, which could be achieved only through excellent workmanship. From a modern point of view this machine would be considered of enormous size compared with its output.

Inductors can be made to be very good generators and synchronous motors, but they are then heavy and very large, as, for instance, this 500-H. P. generator. From considerations of this kind the inductor type has been abandoned by most engineers in favour of the revolving field type, of which some of the latest designs with their details are here to be presented.

Fig. 9, for example, shows a 600-KW, three-phase generator for 2200 volts, operating at 900 revolutions per minute and giving 60 cycles. The peripheral speed of this generator is almost 8000 feet per minute. This high speed necessitates the most careful construction of the revolving part. The poles are fastened to the steel spider by means of dovetails, as shown in the assembly drawing, Fig. 8. The field coils are made of copper strip, wound edgewise, as in Fig. 10.

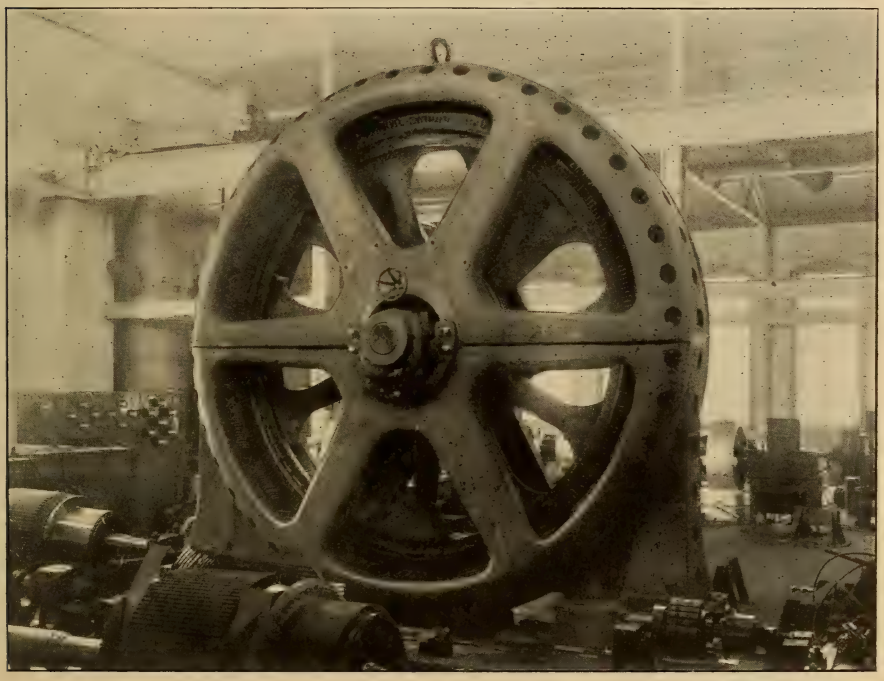


FIG. 15 —A 500-H. P. THREE-PHASE INDUCTION MOTOR

A good example of a modern revolving field three-phase generator is represented in Fig. 11. It is a 1000 to 1250 KW generator for 60 cycles, operating at 180 revolutions per minute, at Cornwall, Ont. It was designed by the author and built and installed by the Bullock Electric Mfg. Co., of Cincinnati, Ohio, U. S. A. To illustrate the safety that can be obtained in these high-speed machines the writer would

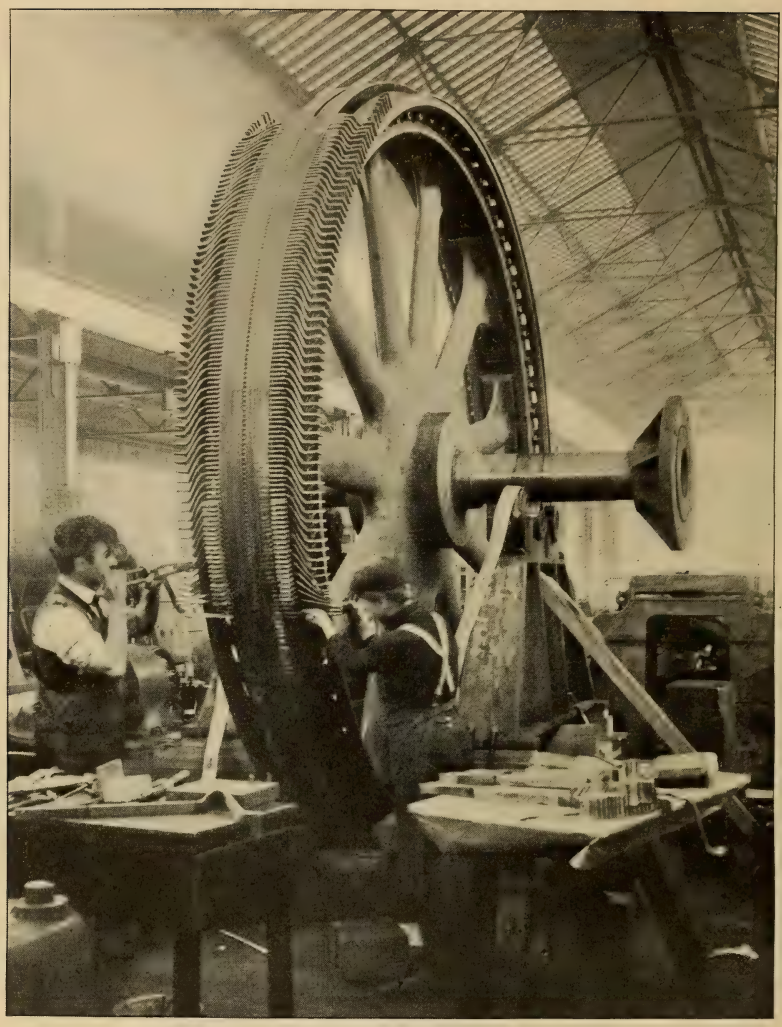


FIG. 16.—ROTOR WINDING OF A 500-H. P. INDUCTION MOTOR

cite an experiment that he made at the Bullock works before the Canadian experts. The revolving field is 12 feet in diameter and runs normally at 6800 feet per minute peripheral speed. Being connected to a water-wheel and thus liable to race, the experts wished to see the machine run at 50 per cent. above normal speed. After removing the men from the shop, the generator was run up to 320 revolutions per minute, corresponding to 12,000 feet per minute peripheral speed. Fig. 12 shows the armature frame in course of construction, the armature punchings being laid into the frame.

Fig. 13 shows a 100-KW alternating current generator for single or polyphase circuits which embodies the most modern features of design, being besides a most compact machine. The exciter is direct connected to the revolving field, which avoids awkward belt drives or gears. The speed of this machine is 900 revolutions and the frequency is 60 cycles.

A type of machine for direct connection to water-wheels with vertical shafts,

developed in Switzerland, and known as the "umbrella type," is shown in Fig. 14. The magnet wheel is keyed to the vertical shaft of the turbine, the arrangement of the armature being clearly shown and requiring no explanation. Such generators have been constructed by Brown for speeds of 360 down to 28 revolutions per minute, and they are remarkable for their elegance and simplicity.

The two types of motors best fitted for alternating currents are the induction motor and the synchronous motor. The latter is in all essentials an alternating current generator, requiring direct current for its excitation. The former type is self-starting, and requires only the two or three alternating current circuits for its operation. Some examples of the induction motor may be alluded to here. In Figs. 15, 16 and 17 are given a general view and details of a 500-H. P., three-phase induction motor designed for driving a large pump in Montreal, Canada. The motor is operated from a 60-cycle, 2200-volt, three-phase circuit, and has, for an induction motor, the abnormally large number of forty-four poles. Its diameter had to be made very large to place so many poles around the circumference. The motor runs at 160 revolutions, and has a diameter of 13 feet. The winding of the stationary part is shown in Fig. 17, while the winding of the rotating part is represented in Fig. 16.

Fig. 18 forms an interesting contrast. It represents small one-half horse-power induction motors driving looms in a silk mill in Switzerland. Each loom is supplied with its own little motor, thus doing away with overhead belts and gearing.

In the matter of using the alternating current for railway work it is to be noted that the first polyphase railway was built in Switzerland, in the beautiful little town of Lugano, at the foot of the picturesque Monte Salvatore. The plant was designed and constructed by the firm of Brown, Boveri & Co., of Baden, Switzerland. The generators are three-phase inductor machines, but they show an interesting novelty, as they have only one armature coil, the pole horns being staggered. The Lugano installation was soon followed by the three-phase rack and pinion railroad upon the Gornergrat, 10,000 feet high, and next

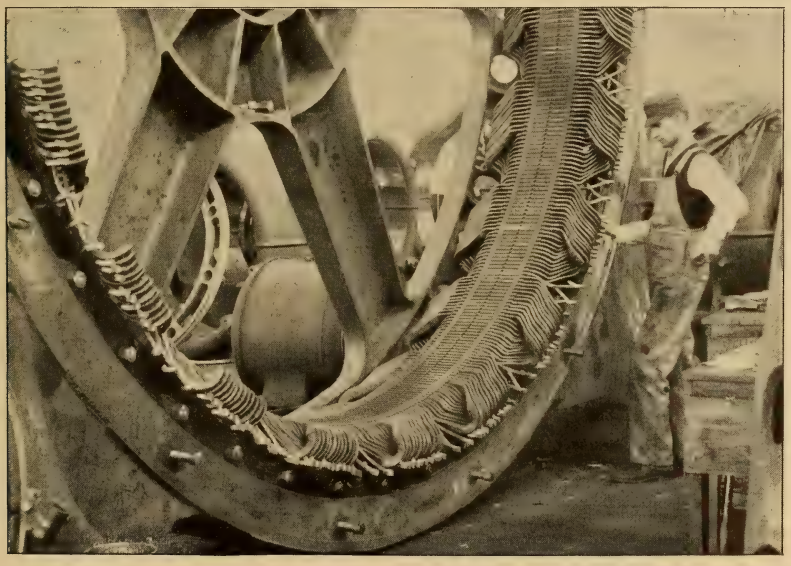


FIG. 17.—THE STATOR WINDING

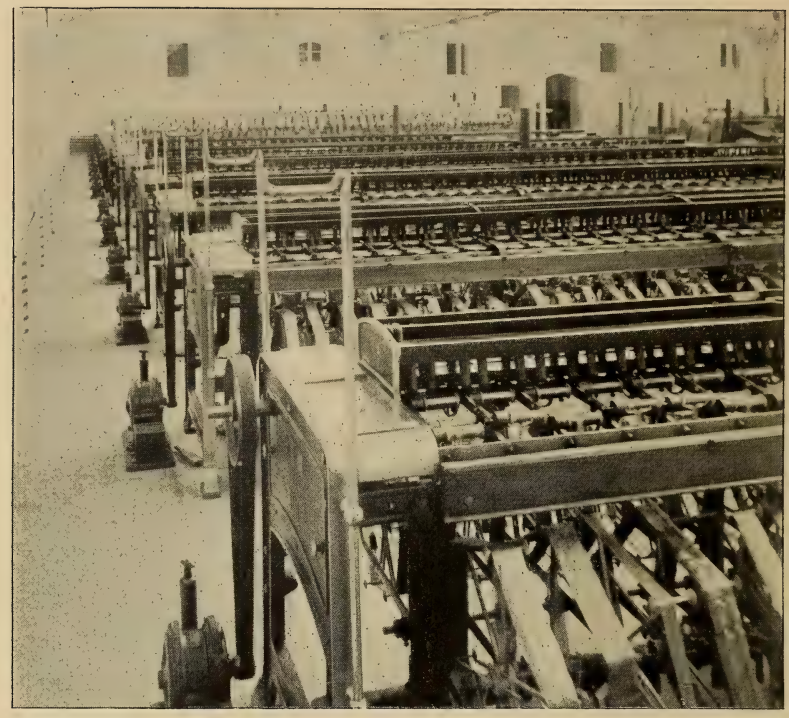


FIG. 18.—INDUCTION MOTORS DRIVING SILK LOOMS IN SWITZERLAND

came the rack and pinion railroad up the snow-clad Jungfrau, that lofty peak of the Berner Oberland, 13,700 feet high. To these bold engineering undertakings has recently been added by the Browns the three-phase trunk railway between Burgdorf and Thun. It would by far exceed the scope of this contribution to give detailed descriptions of these plants, but it will be of interest to mention some of their more distinctive features.

The first two locomotives for the Jungfrau Railway were built by Messrs. Brown, the other two by the Oerlikon Works. Fig. 3 shows the Oerlikon locomotive, which possesses some interesting details. It is equipped with two 125 to 150 H. P., three-phase motors, operating at 550 to 600 volts, and at a speed of 750 revolutions. Between the motors is shown a large rheostat, serving as starting resistance and as brake resistance when the locomotive is going downhill. A small six-pole, direct current dynamo, mounted on a bracket, is driven from the wheels, and when the locomotive is going down it generates direct current for the excitation of the large 125-H. P., three-phase motors, which, being disconnected from the trolleys, act as generators, throwing the energy that the descending car is producing in the form of three-phase currents upon the large rheostat. As is well known, the steam locomotives on the Righi and Pilatus railways act as compressors in going downhill, and a similar method of braking the locomotive is obtained by this electric arrangement. As the evolution of heat by the heavy trains, the locomotive alone weighing fourteen tons, is very considerable, a small three-phase motor, driving a fan which is urging a stream of cold air through the rheostat, is mounted on the locomotive.

The locomotives for hauling freight trains on the three-phase trunk railway between Thun and Burgdorf, a distance of twenty-five miles, are similar to those of the Jungfrau road.

NOTES ON ACCIDENT PREVENTION

IN ENGINEERING WORKSHOPS

By G. W. Bissell

IN Great Britain all industrial establishments are systematically inspected by the government for the purpose of examining and regulating machinery and processes apt to be injurious to operatives, and of detecting and prosecuting infractions of the factory laws. Tables compiled from the annual report of the Chief Inspector of Factories and Workshops for the year 1899 account for a total of 70,760 accidents, 871 of them fatal, and of the total number a large proportion was due to the use of machinery and other tools in machine shops. Thus, in one of the classifications, under the head of "Machinery and Engine Building," the following figures are given:—

Fatal accidents	162
Non-fatal accidents	6,929
Minor	16,554
Total	23,645

This is one-third of the whole number of accidents reported. The report mentioned also contains the following information:—

	Fatal.	Non-Fatal.
Accidents due to cleaning machinery in motion	4	1,073
Accidents due to power presses	0	851
Accidents in connection with lathes	2	2,011
Totals	6	3,935

This total of 6 fatal and 3935 non-fatal, or 3941 accidents in all, occurred in connection with machinery in motion, and does not include minor accidents from which no injury to persons resulted. Statistics along this line are not readily obtainable in the United States, but there is no reason to believe that the results of investigation there would be any more pleasing; indeed, with the lack of government inspection, there is every likelihood that the accident list would turn out to be, proportionately, a much longer one.

For convenience, accidents occurring in workshops may be assigned to those parts of machines or appliances directly chargeable therefor, thus:—Accidents due to gears: those due to belts and pulleys; to shafts and shafting; to grindstones, emery wheels, etc.; and to other causes.

So far as the prevention of accidents from gearing is concerned, the general stand may be taken that all gearing should be arranged to permit of covering every exposed gear wheel with a substantial guard, removable, if necessary, for inspection and repairs while the machine is at rest. Every machine designer knows that the above requirement can be met. In fact, in Continental Europe, where government inspection is the rule, concealed gears are also the

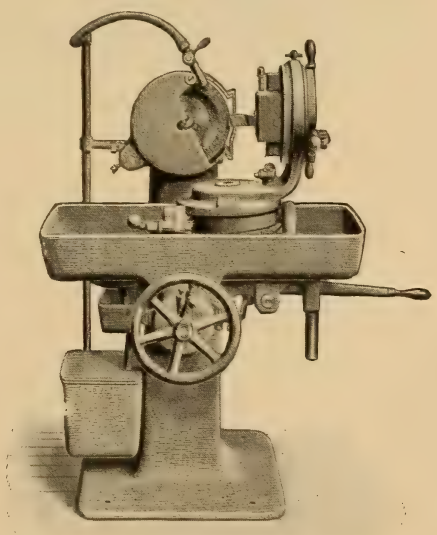
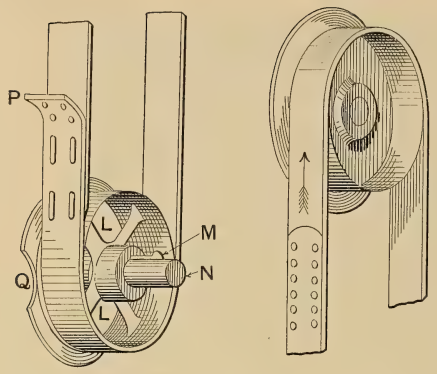


FIG. 1.—A PARTIALLY ENCLOSED EMERY GRINDER



FIGS. 2 AND 3.—THE FORMER SHOWS FIVE POINTS OF DANGER WHICH ARE AVOIDED IN FIG. 10:—*L*, ARMS OF PULLEY; *M*, LARGE KEY HEAD; *N*, PROJECTING SHAFT; *P*, DEFECTIVE BELT LAP; *Q*, CHIPPED FLANGE

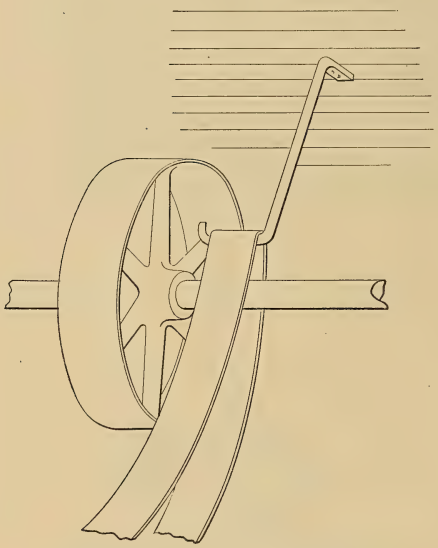


FIG. 4.—A PERMANENT BELT HANGER

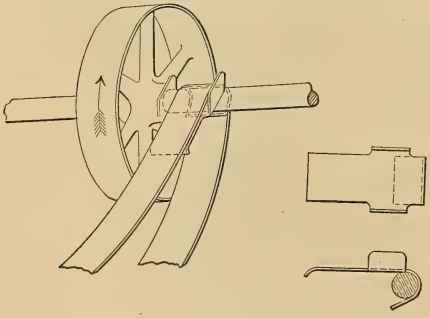


FIG. 5.—A SHEET IRON BELT GUARD FOR USE WHERE A PERMANENT HANGER WOULD BE INEXPEDIENT

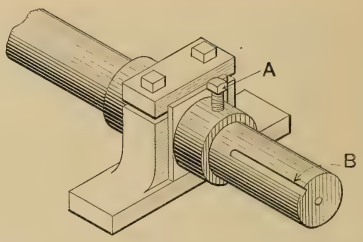


FIG. 6.—A DANGEROUS COLLAR SET SCREW *A*, AND ALSO A PROJECTING SHAFT WITH KEYWAY *B*

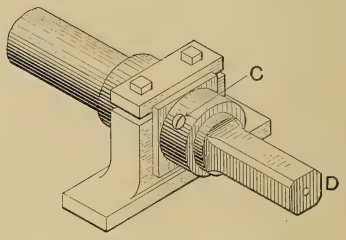


FIG. 7.—A SAFE COUNTERSUNK SCREW, *C*, AND A DANGEROUS SQUARE PROJECTING SHAFT-END *D*

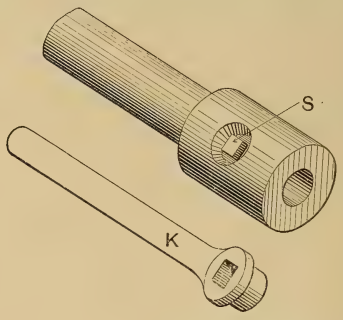


FIG. 8.—SAFE FORM OF SET SCREW, *S*, DEEPLY RECESSED AND ADJUSTABLE ONLY BY BOX WRENCH *K*

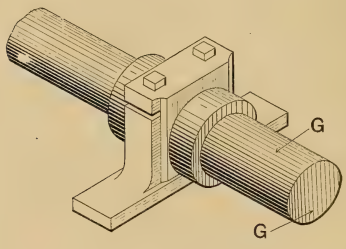


FIG. 9.—METHOD OF COVERING SHAFT ENDS, AS *B* AND *D* IN FIGS. 6 AND 7, WITH A SHEET METAL CAP *G*

rule. American machinery exporters, having to meet this requirement, are gradually reaching the point of concealing all gears on machines for the home market as well, while in machinery of British make the general concealment of gears has for some time been a very noticeable feature.

Good examples of such protected gearing are shown in Figs. 10 and 11. In the latter, the three-jaw chuck also has a peripheral shield to protect the workman from the projecting heads of the jaw-screws. Incidentally, it should be noted that the appearance of the machines is not injured by the gear casings, and the gears themselves are further protected from dirt and mechanical injury.

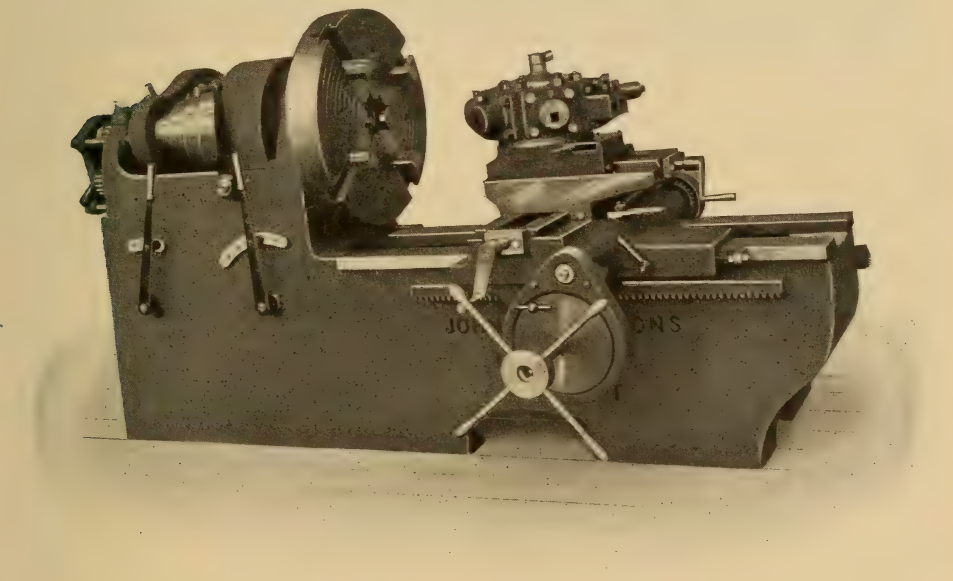


FIG. 10.—SURFACING AND BORING LATHE WITH ENCLOSED GEARS, MADE BY MESSRS. JOHN LANG & SONS, JOHNSTONE, SCOTLAND

In many cases, especially after accidents have happened, it is considered desirable to encase exposed gears of machines not originally so equipped. Sheet steel or brass is well suited for making the casings. Castings are not usually applicable as gear casings on old machines.

Large driving-belts and fly-wheels should be protected by railings of substantial construction, and no unauthorised person should be allowed within such railings. Owing to the well-known carelessness which comes from familiarity with machinery, the railings should be high enough and have enough horizontal rails to remove temptation to pass over or under them.

The dangers of small belts and pulleys lie chiefly in loose ends or flaps, improper lacing, pulleys with arms, projecting hubs with set-screws and keys extending outward on shafts beyond the hubs of pulleys. A little thought and a little daily watchfulness will ensure belts of even surface and good joints, web pulleys, flush-keys, and flush set-screw-heads. At this point it may be interesting to refer to Figs. 2 and 3, the former showing a number of dangerous features, like those just mentioned, all of which have been avoided in the arrangement illustrated in Fig. 3.

In the matter of accidents from shafts, Figs. 6 to 9 are instructive, showing some common defects in shafting arrangements and a few simple remedies

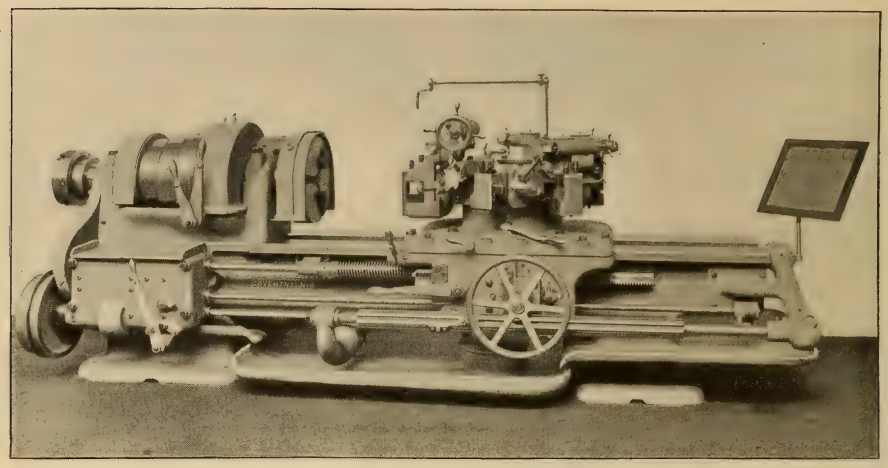


FIG. 11 —HEXAGON TURRET LATHE MADE BY ALFRED HERBERT, LTD , COVENTRY, ENGLAND. THE GEARS ARE ENCLOSED AND THE CHUCK IS FITTED WITH A PERIPHERAL SHIELD

for them. Line shafting should be placed well above the heads of operatives or should be guarded to prevent attempts to pass over or under, and to prevent contact of clothing with shafts, pulleys, couplings or belts. Necessary crossings should be by passages or stairways so constructed as to make the touching of the shafting system impossible by any person or by his clothing.

Belts frequently are thrown off from their pulleys for repairs or other causes. If allowed to lie on the shaft they may be gripped by it and with disastrous results. To prevent this a permanent hanger should be provided for every belt leading from a line shaft, something like that shown in Fig. 4. Where this is not possible a sheet-iron guard may be placed on the shaft under the belt, as in Fig. 5, two ears being bent up to prevent lateral motion of the guard.

A fruitful cause of accidents is found in grindstones, emery wheels and circular saws. The safe speed of rotation should be in all cases known and duly considered. Frequent inspection should be made to detect flaws. Guards should be provided, and the operative and others should, as far as possible, keep out of the plane of rotation.

Fig. 1 shows a partially encased emery grinder. Owing to the extremely high speed at which grinding machinery and saws are run, the principal reliance against accidents due to bursting from centrifugal force must be placed upon conscientious manufacture and good judgment in mounting. Accidents due to catching of the work by the grinder or saw can be remedied by providing automatic or other mechanical holding and feeding machinery, also illustrated in Fig. 1.

It would be quite impossible here to consider, even briefly, all the accidents liable to occur in a shop. The few examples which have been given of ways to avoid some of them are simply illustrative of much that remains to be done in these directions.

LOW-GRADE IRON ORES FOR THE SMELTING FURNACE

CONCENTRATING AND BRIQUETTING

By Thomas Benjamin Grierson

THERE are two classes of iron ore which, while capable of yielding a good quality of metal, are unfortunately, owing to certain physical characteristics, unsuited to the requirements of the blast-furnace. These two classes are mainly low-grade magnetic ores which, in their normal condition, it will not pay to smelt in lumps, and magnetic iron sand which, unless combined with a suitable material capable of withstanding the heat and erosion of the blast-furnace, cannot be smelted in it.

For many years past, as pointed out by the author a short time ago, in a paper read before the Society of Engineers, attention has been directed to making these ores available for the manufacture of steel; but, so far, the efforts made have been attended with only a limited amount of commercial success. The objects in view have been, in the one case, to crush and concentrate the lean ores, and in the other to separate the magnetic iron sand from its accompanying impurities and other undesirable constituents. By means of magnetic separators and cognate contrivances these ends have been satisfactorily attained, but at this point another difficulty arises. In either case the resulting concentrate is generally a comparatively fine powder, which is antagonistic to satisfactory blast-furnace working, even when the concentrate is mixed with ores in masses of larger bulk, except perhaps in very small furnaces. The finely divided ore and ore-dust adhere to the wall of the furnace, causing scaffolding; that is, they gradually form large masses. These masses in time become detached by the pressure of the charge above them, and being thrown down below the zone of fusion, give rise to choking and other incidental drawbacks in the region of the hearth.

In a paper by Professor J. Wiborgh, of Stockholm, read before the Iron and Steel Institute about two years since, it is stated that there are certain conditions which modify the results of using mixtures of lump ores and concentrates in the pulverulent form in the blast-furnace. These are the slope of the boshes and the character of the blast. Professor Wiborgh instances some experiments made in 1898 in the blast-furnace at Vidlitz, in the government of Olonetz, Russia. There the section of the furnace at the boshes was such as appears to be extremely unsuitable for the use of powdered ore. But for all this, the furnace worked satisfactorily, even on concentrates alone, so long as cold blast was employed. When, however, hot blast was used, scaffolding commenced, and continued until the hearth and tuyeres were burnt out.

Another inconvenience attending the use of powdered ores is the loss caused by dust in the gases of the blast-furnace. At Vidlitz from 8 to 10 per cent. of the powdered ore was carried over into the gas conduits. Rich concentrates have, however, been successfully smelted in combination with lump ores, as at the old works of Högfors, in Sweden, as instanced by Professor Wiborgh. But at the best, the proportion of powdered ore that can be used in the blast-furnace is very small, and its employment at all depends upon conditions of fuel and working. The pulverised material,

especially if of high density, has a tendency to overrun the fuel charge and to come down to the tuyeres in an imperfectly reduced condition, as well as to form accretions, or scaffolds, on the walls of the upper portion of the blast-furnace, as already explained. The only way to deal with these finely divided ores is to combine them with some suitable material which will give them cohesion and at the same time assist in the operation of smelting without proving detrimental either to the furnace and its working or to the product.

It would not be possible within the limits of the present paper to describe the numerous devices that have been brought forward from time to time for effecting the solidarity of powdered ores. The author will, therefore, refer only to such methods as are more or less generally known to metallurgists, and to some other processes of a more special character which have been proposed by those having a practical knowledge of the subject at issue. Three principal methods have been practically tried for the purpose of bonding small ore before smelting in the blast-furnace. The first of these is agglomeration by heat, the particles being made to cohere by the action of a reverberatory furnace upon the pulverulent mass. The success of this method, however, depends upon the constituents of the ore itself, or, in the absence of the right kind of constituents, such as silicates, their addition to the ore. Such methods, however, are found to be costly, a high temperature and a lengthened period of exposure being required to ensure success.

A second method is to form the powdered ore into a stiff paste with caustic or slaked lime and water, the lime forming a good binding material. The paste is made into briquettes, which are air-dried and become very hard, the lime, as a silicate, tending to facilitate the working of the blast-furnace.

The third method is the agglomeration of the powdered ore with carbonaceous material and subsequent coking. Professor Wiborgh states that this method was adopted by Weissmann, about eleven years ago, in the production of so-called ore coke which was made by mixing powdered ore with 20 per cent. of coal-dust and 5 per cent. of pitch. The compound was pressed into blocks and coked at a strong heat applied slowly. This method, however, proved too expensive for practical use, but it was revived later on in a simpler form,—namely, by mixing the powdered ore with small coal and coking the mixture in the usual way. Although experimental trials appear to have given good results, the system, so far as the author is aware, has not been adopted in practice, owing to the great cost of production on a working scale.

Among other distinguished metallurgists who have devised methods of using finely-divided iron ore is Mr. James Riley, who proposes to take the slag produced in the manufacture of open-hearth steel, which already contains about 20 per cent. of iron, and to enrich it up to between 40 and 50 per cent. by the addition of finely-divided iron ore. His idea is to mix the powdered ore with the fluid slag as it flows from the furnace or ladle when casting a charge of open-hearth steel. The slag forms a suitable vehicle for conveying the powdery ores to the furnace in a solid state, and the iron already contained in it is, moreover, utilised instead of being a waste product. The possibility of making this conglomerate has been proved in practice by Mr. Riley, he having made and used considerable quantities of it. Special arrangements, however, are necessary before the method proposed by Mr. Riley could become part of the daily routine of a steel-melting shop.

Mr. G. J. Snelus has likewise endeavoured to solve the problem of the utilisation of finely-powdered ores. As far back as 1868 he patented a process for the direct reduction of powdered iron ore into the state of metallic iron. A long series of experiments led him to the conclusion that to obtain metallic iron it is only necessary to expose the finely-divided ore to proper reducing conditions for a very short time. Mr. Snelus considers that the Gerstenhöfer furnace, which is used at Swansea for

calcining iron pyrites, will satisfactorily effect the object in view, if heated with a strong reducing atmosphere. The author, however, is not aware that Mr. Snelus has, as yet, carried his proposition into practical effect.

Later on, namely, in 1884, the late Sir William Siemens endeavoured to utilise the concentrates of poor ores by mixing the powder with tar and forming the mixture into briquettes. These briquettes, in practice, were gradually added to the main charge in Sir William's open-hearth furnace. The results, however, were not satisfactory, and after reasonable trial this attempt to utilise poor ores was abandoned.

Professor Wiborgh, to whom the author has already made reference, has also identified himself with the attempt to utilise poor ores by concentration and direct reduction by designing a furnace for that purpose. This was in 1899, but the author does not think that the invention has been developed into practical use. So far as direct reduction is concerned, the opinion of Sir Lowthian Bell,—one of the highest authorities in metallurgical matters,—is that it cannot be economically effected. This has, in fact, been proved in two instances, one in Great Britain and one in the United States, in which works were started with the object of direct production of malleable iron, but which, in time, were both dismantled.

We are thus brought back to the starting-point, namely, the mechanical reduction and concentration of the poor ore, the incorporation of the concentrates with a suitable vehicle, and the conversion of the mass into briquettes. In this connection the author will, therefore, in the next place, direct attention to the process invented by Edison, who has for some years past devoted considerable attention to the utilisation of poor ores, and whose process for accomplishing this has recently been the subject of a considerable amount of public discussion. In this process, as indeed in all others connected with the present question, the ore is first reduced and concentrated, and then made into briquettes. As there are numerous stone-breakers and ore pulverisers, as well as several magnetic separators in the market, all of which are well known, and all of which are, more or less, suited for the purpose of mechanical reduction, the author need not enter upon this phase of the question. Suffice it to say, however, that the author understands that Edison has invented certain machinery for both these operations. The most important point, to the author's mind, is the conversion of the concentrates into briquettes, and this will be admitted in view of what has already been stated. And here the author is met by a difficulty in not being able to state the ingredients used by Edison in the manufacture of his briquettes, which, he is informed, are a secret. It is, however, stated that there are one or two serious defects in Edison's briquettes. In the first place, they are said to be porous, which alone unfits them, from an ironmaster's point of view, for use in the blast-furnace. Another drawback is that the material used as the conveyor appears to be insufficiently binding to enable the briquette to withstand the burthen in the blast-furnace. A third objection is that the briquettes require to be baked before they are fit for handling, as is publicly stated.

The latest process for the manufacture of ore-briquettes that has come under the author's notice is of British origin. It is that of Mr. Robert F. Strong, who, like Edison and others, has for long past given much time and attention to the utilisation of poor iron ores, and particularly to the manufacture of ore-briquettes. Mr. Strong has not devised machinery for the mechanical reduction or for the concentration of the ore, but confines himself to putting the ore into a suitable condition for use in the blast-furnace. To this end he makes his briquettes of 85 per cent. of concentrate, with which he incorporates 5 per cent. of powdered quicklime and 10 per cent. of pyroligneous tar. The mass is formed into briquettes under pressure, the briquettes being ready for use directly they leave the press, and not requiring to be baked. The tar in the briquette is of assistance in economising fuel in the

blast-furnace, whilst the quicklime forms the best possible binding material and also assists as a flux. Assuming the concentrate to contain 75 per cent. of ore, which it does on the average, the briquettes would contain 63.75 per cent., equivalent to about 48 per cent. of metallic iron. The briquettes would be manufactured at the mines at which the ore is produced, and delivered to iron-works in England at the market price of ore. They would, however, have an advantage over the raw ore, owing to the fact that they would be more easily reduced and with a saving of fuel.

Such is the briquette which Mr. Strong has devised for employment in the ordinary blast-furnace using ordinary coke fuel. He has, however, devised another ore-briquette for use in the charcoal furnace in which the ingredients are varied. In the ordinary furnace,—except in very small ones,—the charcoal will not carry the burthen. With small furnaces the production is necessarily restricted and costly. To meet this and to enable the briquettes to be used in blast-furnaces of full size in those countries where charcoal is employed as a fuel, Mr. Strong combines powdered charcoal with the other ingredients, adding also granulated limestone as a flux. By this means charcoal pig-iron could be produced in the ordinary blast-furnace at a less cost than common foundry pig, and this charcoal pig would be available for ordinary steel-making purposes with the result of greatly improved products. The pig-iron would thus be produced at the mines and no carriage or freight would have to be paid upon the ore. The cost of transport to the steel works would be that of the metallic product alone.

As regards the cost of mining and concentrating the ore, ready for the briquette factory, the author gives the following figures, which are those of actual working at a mine in Sweden. At the present time the cost works out at 4s. 3d. per metric ton of 75 per cent. concentrates. This includes miners' wages, tools, explosives, crushing and concentrating, loading and transport to the briquette factory, and management, which come to 1s. 8¼d. per ton of raw ore. But it requires two and one-half tons of 30 per cent. ore to give one ton of 75 per cent. concentrates. Therefore, 1s. 8¼d. × 2½ tons = 4s. 3d. (about), which is the cost of one ton of 75 per cent. concentrates in Sweden, equivalent to 63.75 per cent. per ton of briquettes.

Briquettes, to be of any use in the blast-furnace, should be hard, non-porous, impervious to moisture, and capable of standing rough treatment, in the same way as large raw ore. These qualities will enable them to resist the great superincumbent weight in the blast-furnace, and the slow grinding action, which tends to disintegrate them. Above all, they must be able to withstand the gradual increase of temperature in advancing to the melting-point, almost up to which point they should retain their form. This, in the author's opinion, is precisely what the British briquette will do and what the American briquette will not do.

The briquettes are put into the blast-furnace and smelted in the usual way, but instead of the quality of the metal produced being largely dependent upon the attendant whose duty it is to feed the furnace, the briquettes when smelted produce, almost automatically, the proper material required, the proper proportions of the ingredients being fixed and invariable in the briquette.

With the present arrangement, especially during night shifts, any neglect on the part of the man in charge of the furnace in not putting in the proper relative proportions of materials would, and no doubt sometimes does, result in the metal not being uniform in character, or perhaps quite useless for the purpose intended. With briquettes this could not happen, as they would be composed of the exact quantities of the ingredients required to produce a specific result. The weighing of the ore, fuel, etc., in the method now in vogue, and the constant attendance on the blast-furnaces while the smelting is going on, involve considerable expense for labour, a large amount of which would be saved by the adoption of the briquette system. The author believes that the general adoption

of the method of making steel from briquettes would result, not only in large saving in cost of production, but also in a much more uniform and better quality of the steel produced.

The materials for making the briquettes are to be found in great abundance in Sweden and Norway, Spain, Canada, New Zealand, and Ireland, the last-mentioned country having also immense deposits of peat, from which a suitable tarry acid for the briquettes could be obtained.

With the view of ascertaining their adaptability for the blast-furnace, briquettes made on Mr. Strong's system have been tested at the Leeds Steel Works, at the Normanby Iron Works, Middlesbrough, and at the Clyde Ironworks. The briquettes were tried in various kinds of furnaces for temperature, and they were also tested mechanically for carrying the burthen, and both as regards their behaviour at the highest temperatures and their resistance to crushing, they were found, in all cases, to stand equal to raw ore.

Although the present paper deals with the treatment of iron ores, the author may mention that Mr. Strong's system has been adopted at the Broken Hill Mines, in Australia, where it has been in successful operation for the past two years with silver ore concentrates. It has also been in use for the last eighteen months at the Rio Tinto Works, in South Wales, where it is working upon copper concentrates.

Current Topics

A NEW arc lamp, known as the Bremer lamp, brought from Germany, and for which high efficiency and an agreeable quality of colour are claimed, has recently been put on exhibition. Its efficiency is said to be about twice that of the ordinary arc lamp. It employs two carbons of small diameter, the positive one about 0.27 inch and the negative one 0.23 inch in diameter. The positive carbon is cored, and contains magnesia and other metallic salts, and boron in certain proportions; the negative carbon is solid. The boron acts as a flux, thereby preventing an accumulation of a refractory scoria that would otherwise surround the ends of the carbons and reduce the efficiency and reliability of the lamp. The carbons approach each other at an acute angle, and their lower ends are enclosed in a metallic chamber having an opening in its under side. In the operation of the lamp the magnesia is slowly vapourised and gives off a snow-like dust, which settles on the inner surface of the metal

chamber. This deposit is found to act as an excellent reflector, throwing the light downward and thus adding to its efficiency. The light can be made of any desired colour by varying the ingredients in the cored carbon. The carbons are fed by gravity, and the length of the arc is regulated automatically by the lever of an electromagnet suitably placed.

ALMOST since its inception many well-meaning people have taken exception to the use of the term "wireless" in connection with electric wave telegraphy, and numerous substitutes have been offered, for instance, etherography, syntonography, and the like, but so far these suggestions have fallen flat. Etherography is quite as applicable to heliography and to ordinary telegraphy as to wireless telegraphy, and there is no good reason for the term syntonography. Wireless, indeed, is as convenient and significant as any other name that might be chosen. The exception to the name is that wires are still employed in the apparatus of this system, which is true; but so they are in wire telegraphy in relays, etc.; yet no one ever thinks of the latter in connection with wire telegraphy. The fact is, that the connecting wire between a sending and receiving station was looked upon as absolutely essential to telegraphy up to the time of electric wave telegraphy, and it was the ability to dispense with this connecting wire that produced the profoundest impression on the public mind; hence, the term wireless telegraphy was singularly apt. If another name be desired, it will be easy to follow the precedent already set in the case, for instance, of Morse telegraphy and Wheatstone automatic telegraphy, and term it the Hertz, Lodge, Marconi or other wireless telegraphy, as the case may be.

THE fact that the German Government has ordered the Slaby-Arco system of wireless telegraphy for its war vessels would appear to show that the Marconi system is not to have the world-wide monopoly that has been expected. Rumours also come from German sources that the operation of the wireless systems on the Hamburg and Bremen line steamships *Kronprinz Wilhelm* and *Deutschland* during the recent trip of Prince Henry to the United States was not as satisfactory as could have been wished. The difference between the Marconi and the Slaby-Arco system is one of details. Both systems use the oscillator, the Branly filings coherer, the Lodge tapper, the vertical wire, relays, and other devices. For tuning, however, the Slaby-Arco system is based on a theory which Marconi has pronounced to be faulty. For each system advantages are claimed in the particular arrangement and construction of apparatus. In the meantime, Branly, the inventor of the filings coherer, without which wireless telegraphy, as it now exists, would be impossible, has been at work devising another type of coherer which he claims to be much superior to his filings coherer. The new coherer consists of a tripod of iron or other metal,—large iron needles will do,—resting on a plate of steel. The tripod forms one terminal of the coherer and the steel plate the other terminal. The only conditions are that the steel plate must be polished, while the feet of the tripod resting on the plate must be oxidised, or rusted. It is stated that this coherer is much more sensitive, decoheres more readily, and is more durable than his filings coherer. A Parisian company has been organised to exploit the invention.

OMNIBUSES and country road waggons driven electrically, from overhead wires and trolleys, appear to be the fashion just now. Several different kinds have made their appearance within the past year, developments apparently of an idea first advanced, as it is now recalled, four or five years ago somewhere in the United States. The short line equipped at that time involved the use of a double-trolley arrangement, two

wires being run about 17 feet above the ground and about 18 inches apart. The trolley device consisted of a metal frame with two overrunning trolley wheels, with locking wheels underneath which prevented the top wheels from leaving the wire without obstructing the free passage of the frame over the supports on the poles. On the lower wire a similar device was used, and both sets of trolley wheels were connected by an insulated pantograph arrangement which provided for unequal tension on the trolley wires. Connection between the trolleys and the waggon was made by cables running on to an automatic reel on the waggon. This permitted the cables to run out a few hundred feet if necessary, or wound them up to a short length, giving the waggon considerable freedom in direction of travel, enabling it to readily turn out of the way of obstacles and to follow twists and turns of the road without difficulty, even though the pole line took a somewhat different and possibly more convenient course. The current was led to a 2 H. P. motor on the waggon.

This brief recapitulation of particulars of that early line has a renewed interest in connection with what has latterly been told of two overhead electric trolley omnibuses now in use on one of the routes in the suburbs of Paris, and which, it is thought, may help materially in solving the transportation problem in sparsely populated districts unable to support the ordinary system of electric tramways. It may be said here, by the way, that running electric omnibuses with overhead trolleys was tried at the Paris Exhibition two years ago, but failure in that instance was ascribed to the fact that the trolley with its connections had to be towed behind the bus, and variations in the speed and in the line traversed by the bus caused jamming and other difficulties. In the new route, which is said to have been in operation for some time, the trolley running on the overhead wires is self-propelling, being ingeniously arranged to run with a three-phase motor, the transformed current coming from the omnibus, so that the speed of the self-propelling trolley varies directly with the progress of the bus itself, and thus it travels at a regular distance in advance of the bus. The self-propelling trolley weighs forty-four pounds, and the connection between it and the bus, as in the earlier trials above recorded, is in the form of a cable sufficiently long and flexible to allow the bus to go at will from one side of the thoroughfare to the other. The whole length of the route on which the system is at work is over three miles, and the total cost of installation with the two buses is £3800. The vehicles weigh, with their load, three and one-quarter tons, and carry eighteen passengers, and make the trip of three miles in twenty minutes.

It is not generally known to users of the telephone,—and perhaps it is just as well for the interests of the service,—that when the ear-piece of a receiver is held to the mouth-piece of the transmitter a more or less shrill tone or whistle is heard in the receiver. This occurs when the apparatus is in good working condition and when the transmitter is on short circuit. This effect is seemingly due to a series of reactions analogous to, but much more complex than, those which occur in an electric bell when its circuit is closed. A movement of the diaphragm of the receiver towards its magnet tends to weaken the pressure on the carbon of the transmitter, which causes a weakening of the current, allowing the diaphragm to fall away, with the further result that the air column is compressed, increasing the pressure on the carbon again, and also increasing current strength, whereby the diaphragm is again attracted, and this action is repeated over and over again. Recent investigation of these phenomena indicate, as might be anticipated, that they are dependent upon the fundamental rate of vibration of the receiver and transmitter, the length of the air column enclosed between them, and also the oscillation period of the circuit. The above references to the attraction of the dia-

phragm and to its falling away are, perhaps, rather broad terms, when it is considered that as near as can be calculated the amplitude of vibration of the diaphragm of the receiver in reproducing speech is about the one twenty-millionth of an inch.

CONCERNING the increasing frequency with which condenser tubes in warships are giving out, the *Engineer*, of London, says that experience in United States naval vessels at least appears to locate the trouble mainly in the too small size of the condensers for their work. The most noteworthy defect is that the tubes disintegrate and lose strength a short time after they have been put to work. They become so brittle that they may be broken up into small fragments with the greatest ease. It is held that this result is due to the tubes being called upon to transmit too much heat,—that, in short, the passage of successive waves of heat as the exhaust ports open and close works a molecular change. Formerly twice to two and one-half times as much cooling surface was allowed for a given power as is now available, and there was no trouble. There is practically no trouble now with condensers in the mercantile marine. How or why the transmission of heat should operate to this end is not stated. There is, however, another cause of disintegration at work; the tubes used are very long, and the diameters small. Tubes ⅝ inch in diameter and only 18 or 20 gauge thick are quite common. When the steam rnshes into the condenser in rhythmical beats, it apparently sets the tubes vibrating, and this may go far to explain the brittleness which undoubtedly is manifested by the tubes, and that to a very remarkable extent after they have been in use some time. Furthermore, it is the fixed opinion of competent authorities that simply drawing a 16-gauge tube two gauges thinner, or down to 18 gauge, notwithstanding the annealing, "takes the life out of the metal,"—that, in fact, the thin tube cannot be equal in quality to the tube which is thicker. These facts and opinions deserve carefu consideration from metallurgists. Turning, now, to other causes of failure, it is found that when corrosion takes place it always occurs on the sea-water side o the tube; the steam side remains unaffected. The tubes most likely to fail are those near the top of the condenser which receive the first blow of the exhausting steam. These tubes fail either because of the destructive molecular change named, or from pitting, or because they split. Again, the tubes are all packed with tape and screwed glands, and with thin tubes,—Nos. 18 or 20,—it is very difficult to keep the ends tight. The tubes, it seems, will not stand up to the pressure of the packing in the tube plates, and leak. The remedy is simply to use much larger condensers, with more tube surface, and more widely-spaced and heavier tubes,—in a word, condensers more like those in the mercantile marine. The rage for keeping down the size and weight of machinery in fighting ships seems likely to be followed by a reaction in favour of more generous treatment. It is, at all events, certain that the present policy of cutting down everyth'ng seriously imperils the efficiency of warships. A few tons more in the engine room would make no perceptible difference in displacement, but it would make all the difference in the world in the efficiency of the ship as a fighting unit.

IN the same article the *Engineer* remarks that copper may be said to have enjoyed the reputation of being akin to precious metals. It does not corrode like iron or steel. It is fairly flexible, ductile, and in various ways an excellent engineering material. Not until within comparatively recent years have doubts been thrown on it. These were created by certain steam pipe fractures which occurred soon after high pressures were adopted at sea. While pressures did not exceed 40 pounds or so there was no trouble; as soon as they got to 160 pounds steam pipes began to lose their reputation. Various inquiries were car-

ried out. It was early learned that it was not the higher pressure alone that was at fault. The diameters of the pipes admitted of being reduced as the pressure augmented. The principal fact which came into prominence was that copper is much reduced in strength by being heated. But this was not all. There is good reason to believe that copper is a highly unstable metal. It is known that all metals are liable to molecular change, and that they depend for their resisting power very largely, and in some way not at all well understood, on their temperature. Thus, for example, a small rod of tough soft steel, which may be tied at the ordinary temperature of a room into a knot, will, if chilled in liquid air, fly into a dozen pieces if struck with a fitter's hammer. Copper, if heated and cooled repeatedly, appears to undergo a distinct molecular change. Hitherto it has been supposed that this change took place only at high temperatures. It has been known, indeed, for some time that the copper winding used in electro-magnets and dynamos undergoes deterioration. This has been attributed to the action of the electric current, which operates in a way not understood, and the facts have not been regarded as of any significance for engineers. The range of temperature in wire of the kind being too small, it is asserted, to be influential, the change is attributed to electricity alone. From what has been said in the preceding paragraph, however, it may seem that this is a mistaken view, and that even at quite low temperatures a ruinous molecular change may take place in copper and in certain of the alloys of which it forms the main constituent.

MASURITE is the name of the latest high explosive put on the market. It appears to be in every sense a safe explosive, failing to detonate under the most trying conditions that are ever likely to be brought about accidentally, and yet affording admirable evidence of great destructive power at the right time. It takes its name from its inventor, Mr. F. L. M. Masury, the head of the Masurite Explosive Company, of New York, under whose supervision a number of very striking tests on a working scale were recently carried out at his country residence for the benefit of a small group of interested spectators. These tests demonstrated in a satisfactory way that masurite was insensible to shock, concussion, heat, or cold, as far as its liability to explode by any of these means was concerned, and that it could be exploded in the proper manner only by means of a double-strength exploder. One of the tests consisted in striking a quantity of the explosive with a hammer and a 16-pound sledge, both on stone and an anvil, and in allowing a 50-pound weight to fall 25 feet upon a masurite cartridge,—all without other effect than breaking up the cartridge and scattering the explosive. Masurite in cans was shot through with both steel-jacketed and mushroom bullets, and even heated by burning coal and then shot through without exploding. Red-hot irons were run through the powder, both loose and in cartridge form, the result being simply to fuse and burn it while in direct contact with the heated surface, the powder going out upon removal of the iron. A bundle of parlour matches ignited in masurite had their flame immediately extinguished. Black and smokeless powder were set off on top and below a heap of masurite, and merely blackened it. Electric sparks were made to play in contact with the material, and no explosion resulted. For friction tests masurite was rubbed to dust between sandpaper and emery cloth.

IN a series of detonation tests it was found that a masurite cartridge on exploding would explode another one placed in contact with it, but when it was 12 inches distant the unprimed cartridge was simply torn and the contents scattered. With a 40 per cent. dynamite cartridge exploded at a distance of 12 inches from a masurite cartridge, the latter did not go off; but with reversed conditions an unprimed dyna-

mite cartridge readily exploded. To show that masurite does not freeze at low temperature, a cartridge of masurite was placed in a freezing mixture at 6 degrees below the Fahrenheit zero for three hours. When taken out it was found to be entirely loose, and was immediately exploded with great violence by means of an electric fuse. To show the relative force of masurite for rock work, a large boulder, in which were placed twelve cartridges in two bore holes, was blown to pieces. The masurite used in all these tests had a strength equal to 40 per cent. dynamite, and this can be increased or decreased, as desired, in making the explosive. A notable feature of masurite is the flameless character of its explosion. This was particularly evident when dynamite and masurite were exploded together, the former giving off a vivid flare of light. In this absence of flame, according to Mr. Masury's claims, lies the great value of masurite for coal-mine work, as it will not ignite coal gas or dust in the neighbourhood of a blast.

Some figures given recently by Rear-Admiral Charles O'Neil, Chief of the Bureau of Ordnance of the United States Navy Department, afford interesting data as to the ammunition expended in the naval battles of Manila and Santiago during the late war between Spain and the United States. In the fight at Manila the United States ships expended 132 tons of ammunition, including powder; the cost was $50,044. Nearly 67 tons of metal were thrown in 5858 discharges. Of these, 1413 rounds were fired by the main batteries of the fleet and 4445 by the secondary batteries. The ammunition expended in destroying the Spanish fleet off Santiago amounted to 164.7 tons; the projectiles thrown weighed 114.3 tons. Thirteen hundred rounds were fired from the main batteries, 8174 from the secondary, a total of 9474 rounds. Of this number only 124, or 1.3 per cent., are known to have hit their marks. The *Oquendo* was struck 61 times, the *Viscaya* 28 times, the *Maria Teresa* 29 times, and the *Colon* 6 times. Recent target practice in the British Navy has developed a very much greater percentage of hits, yet in that practice the targets were stationary, and the vessels firing were moving at a fixed speed. In the battle off Santiago, however, the targets were moving as rapidly as they could and the pursuing vessels following at constantly increasing speed. As the figures stand, the cost of ammunition to the United States in defeating Spain at sea was only about $175,000, of which $134,909.11 was spent in the two decisive battles of Manila and Santiago.

Out of the number of clever people on the staff of a large metropolitan daily paper it would seem there would be one who would have the requisite technical knowledge to intercept the serious, but erroneous, conclusions on scientific subjects that more or less frequently appear in the columns of the daily press, and which the technical press is fond of terming "newspaper science." An example of what is referred to occurred recently in an editorial based upon the telegraphic report of what purported to be a new invention, namely, the joint use of a wire for telegraph and telephone purposes. The editorial discoursed at length on the possibilities opened up by this invention, and made the usual prediction that if subsequent tests bore out the results of the first experiments, it would work a revolution in the arts of telegraphy and telephony. As a matter of fact, however, it is to be noted that the joint and simultaneous use of a wire for telegraphic and telephonic purposes was invented prior to 1884, and the system is to-day in use on hundreds of miles of wire. By the use of this system, the invention of Von Rysselberghe, a Belgian, two telegraph circuits are obtained from any metallic telephone circuit on which it is placed, without detriment to the operation of either system.

Another instance of non-familiarity with simple scientific facts is illus-

trated by an article that goes the rounds of the press once or twice annually, namely, the story of the electrified house. The article usually states that some one has discovered that everything he touches in his house, the radiators, picture frames, banquet lamps, etc., give him an electric shock. Hence, he fears there is some connection between the arc-light wires and the water pipes near his residence. The electric light inspector is, therefore, summoned, and reports that the wires of his company are intact and that the electricity must come from some other source. It does not dawn on any of the people consulted that the discoverer of the phenomenon is unconsciously performing one of the simplest and oldest of electrostatic experiments, the shuffling of his shoes over the dry carpet raising the potential of his body to several thousand volts which discharge at every opportunity. One may even get electric discharges from his knuckles to the brass lock of a hand-bag which he may be carrying while walking on a stone pavement during cold, dry weather. But, dismissing newspaper science, it is somewhat astonishing, in view of the many ways in which in cold, dry countries electricity is unintentionally developed and manifested by sparking, that the first knowledge concerning this phenomenon did not come to the ancients in this way rather than by the attraction of light substances by amber. The explanation of this, however, may be that the scientists of bygone days did not reside in cold, dry countries.

EDWARD GOODRICH ACHESON

The Inventor of Carborundum

A BIOGRAPHICAL SKETCH

By J. A. J. Fitzgerald

THE Acheson family originally came from Scotland about the beginning of the seventeenth century and settled in Glassdrummond, County Armagh, Ireland. Passing over more distant ancestors, we find that about 1770 David Acheson, the youngest of seven children, was born, and at the age of eighteen emigrated to the United States, on the advice of his elder brother, John, who was then in successful business at Washington, Pa.

On his arrival he was taken into partnership by his brother, who had contracts with the United States Government for furnishing various supplies to the army. David Acheson was successful in this business and became prominent in public life, being elected three times to represent Washington County in the Pennsylvania State Legislature. He was personally acquainted with George Washington, for we find that he was honoured with an invitation to dine with the President in February, 1797.

David Acheson had twelve children, among them being William Acheson, the father of E. G. Acheson. The former was born in 1818, and originally began the study of medicine, but gave this up on account of serious financial troubles affecting his father, and started a grocery store. Although forced to take up this business, he was a man of scientific tastes, and was evidently a clever mechanic, for Mr. E. G. Acheson has told the writer that he distinctly remembers a very ingenious "buggy," or baby carriage, that he designed and built for his children. He continued in the grocery business till 1863, when he became manager and part owner of an

ironworks started at Monticello, Pa., in which he met with undoubted success, since Monticello iron became a well-known brand in the Pittsburgh market.

Edward Goodrich Acheson was born in 1856 and was educated at Bellefonte Academy, Bellefonte, Pa. From an early date his mother's training developed in him an unusual interest in scientific subjects, and we find him filing a caveat in the Patent Office at the age of seventeen for a drilling machine to be used in coal mining. It is interesting to note that one of these machines built by him was actually in use as a drill in a waggon shop at Kittaning, Pa., in 1886. In 1872 he was taken from school and employed at his father's blast-furnace. After the death of his father in 1873 he changed from one employment to another, finally becoming attached to a surveying party as chainman. He advanced rapidly in this work, and soon had charge of a transit, but after about two years he left this work and was employed by the United Pipe Line Company. During this time, however, his chief interest was in electricity and chemistry, and all his spare money was spent in making electrical and chemical experiments, greatly to the distress of those who knew him and who looked on his experiments as the height of folly.

His facilities for scientific studies were very poor, but he made the most of what was at his command, and at the age of nineteen drew up a pocket chart of the elements and various other bodies, with all available information as to atomic weights, densities, electrical and heat conductivities, etc. He also designed and built a dynamo to be again mentioned later on. He wrote papers on various scientific and engineering subjects, one of which was on the protection of oil tanks from lightning, and advocated connecting the lightning conductor to the oil tank instead of insulating it, as was then the practice. This article was published in a Bradford, Pa., daily paper, having been declined by one of the technical papers on the ground that it was too revolutionary, being contrary to the best engineering practice. It is scarcely necessary to remark that eventually the soundness of young Acheson's proposal was recognised.

About 1880 he determined to get a position with some electrical firm, and he therefore wrote to Mr. Weston, of Newark, N. J., asking for a place. To this letter he received an answer to the effect that employment could not be given to him; but this did not satisfy him, and having saved a little money he went to Newark to get a personal interview. He was not successful in getting a position, and after some failures elsewhere he finally went, in September, 1880, to Edison's laboratory at Menlo Park, where he fortunately got a position as assistant in the draughting room. He had brought with him the dynamo already referred to, and showed it to Edison, who said it was old and directed him to a certain book in the laboratory library. Mr. Acheson was then greatly disappointed to find that his machine, which he had supposed to be original, was identical with the Siemens dynamo. Edison soon recognised the ability of his new employee and transferred him to experimental work; and presently he received the following letter:—

NEW YORK, April 20, 1881.

MR. ACHESON, MENLO PARK, N. J.

DEAR SIR—You had better go into the lamp factory and learn the lamp business in all its details.

Yours truly,

THOMAS A. EDISON.

Two months later, or nine months after arriving at Menlo Park, Mr. Acheson sailed for Europe, as assistant in charge of the Edison electric light interests at the Paris Exposition.

He remained in Europe for three years, and in that time installed lighting plants at various places,—Milan, Brussels, Pisa, Bergamo, Genoa, and Antwerp, and at the end of 1882 left the employment of the European Edison companies to undertake some experiments on his own account. These related to batteries and thermopiles, and were carried on in Paris and London until finally, in 1883, he became ill in the latter place, and on recovery found himself without any money. On communicating with Edison, the latter cabled for him to return to America, and he was with him for a short time, but soon left to continue his own experiments.

Having again exhausted his resources, he accepted a position as superintendent of the Consolidated Lamp Company, of Brooklyn. Shortly afterwards he married, and, leaving the lamp company, again started experimenting, which he continued until 1886, when having once more spent all his money, he became connected with the Standard Underground Cable Company. Here he remained till 1889, and then left in order to return to his experimental work.

During these various periods of original investigation he had taken up a great variety of electrical subjects, but now he devoted himself exclusively to the problem of the direct conversion of heat into electricity. In 1890 he organised an electric light and power company at Monongahela, Pa., with the object of facilitating his experiments and obtaining a laboratory. In March, 1891, he found himself in an unfortunate situation, for the company he had organised was not paying and those associated with him wished to abandon the business.

About ten years before this, while experimenting in Edison's laboratory, he had produced a small quantity of a substance that was harder than emery or corundum, and this had suggested to him the great value of a harder abrasive than those in ordinary use. As a last resource at this later date, he determined to make further experiments in this direction. He placed in an iron bowl a mixture of clay and coke, and introduced an arc-light carbon into it. The bowl was connected to one terminal of a dynamo, the carbon rod to the other, and a current sufficient to raise the mixture to a very high temperature passed through it. After the experiment he found on the carbon rod a few bright-blue crystals of great hardness. He then built a small furnace of a more practical form, and for six months produced this new compound, which he called "carborundum," at the rate of about a quarter of a pound a day. Feeling confident of the great industrial value of his discovery, he formed the Carborundum Company, and began the manufacture of the material on a larger scale.

Fully convinced that the new abrasive was far superior to emery or corundum, he expected to sell it to the emery wheel manufacturers. In this, however, he was mistaken, for the emery wheel makers could see no value in it, and he was thus driven to take up the manufacture of carborundum wheels himself. After much experimental work satisfactory wheels were made, the principal market for them being found in dental work. About this time the Westinghouse Company undertook the work of supplying the Chicago World's Fair with incandescent lamps of the "stoppered" form, a very big undertaking, which was made possible by the use of carborundum wheels for grinding out the lamps.

In spite of the business thus secured, the Carborundum Company was not making money, and in 1894 Mr. Acheson concluded that in order to make carborundum an industrial success it would have to be turned out on a large scale. He, therefore, decided to build a factory at Niagara Falls, equipped with 1000-horse-power furnaces. This scheme was bitterly opposed by those associated with him in the company, but meanwhile he had sold some of his foreign patents for a good sum and with this money he built the Niagara Falls works. It is only fair to state that the opposition he met with was apparently reasonable, for of the 52,000 pounds of carborundum manufactured in 1894 not more than one-fourth was marketed, and the estimated production of the Niagara Falls works was 1,000,000 pounds a year.

The Niagara factory was started in 1895, and Mr. Acheson hoped once more that with the greatly reduced cost of carborundum the emery wheel makers could be induced to take it up; but in this he was again disappointed, and was accordingly compelled to continue the manufacture of wheels on his own account. While great success had been met with as long as the wheels were used in places where their high price was of small consequence, it was found impossible to compete with emery wheels for general service. The next three years were, therefore, largely de-

voted to the problem of perfecting the carborundum wheel so as to enable it to successfully compete with the much cheaper emery wheel.

Meanwhile, carborundum was being manufactured at the rate of considerably over 1,000,000 pounds a year, and a further outlet for it had to be found. In order to dispose of part of this large production Mr. Acheson put up a plant for the manufacture of carborundum paper and cloth. Considerable sums of money were necessary to carry out these plans, and were obtained by Mr. Acheson at great personal sacrifices; but this was entirely in keeping with the character of the man who, as a boy, spent all his spare time and money on his experiments. Finally, about 1897, the difficult problems connected with the manufacture of carborundum were successfully solved and Mr. Acheson was able to turn his attention to other matters.

In the early days of the manufacture of carborundum Mr. Acheson had found in his furnaces a form of carbon which had all the properties of graphite. This was formed by the decomposition of carborundum, or, to give it its chemical name, silicon carbide, the silicon being vapourised and the carbon left behind as graphite. Further experiments had shown that graphite could be obtained in the same way from other carbides, and he now set to work to develop the commercial production of graphite from amorphous carbon in the electric furnace. At first he devoted himself to the manufacture of graphite electrodes for use in electrolytes where amorphous carbon would be rapidly disintegrated, and in 1897 he manufactured and marketed over 162,000 pounds of graphite in this form. Meanwhile, he was experimenting on the production of graphite in bulk, and found that the best carbonaceous material for this purpose was anthracite coal.

In January, 1899, he organised the Acheson Graphite Company, and drew up the plans for a factory with 1000-horse-power furnaces. In 1900 he organised the International Acheson Graphite Company, with control of the foreign patents for the manufacture of graphite, and then merged with this the Acheson Graphite Company. The factory was started in August, 1900, and with furnaces not only for the manufacture of graphite electrodes, but also for the production of graphite from anthracite coal. The business of the graphite company has steadily increased since then, and in 1901 about 2,500,000 pounds of graphite were produced, of which 1,100,000 pounds were in the form of electrodes. This industry promises to be of great importance not alone in assisting the development of numerous electro-chemical processes, but also in providing for other purposes a graphite that is in many ways superior to the natural product.

It is always interesting to find out on what qualities success depends, but it is by no means easy to do so in the present case, for here we have a combination of many different qualities that are not usually associated in the same person. In the first place, Mr. Acheson is a skillful experimenter and an ingenious inventor, and with this he combines a courage that no failures or adverse conditions can daunt. Above all is a remarkable personality which compels confidence from others, and which enabled him during the years of serious business depression to obtain the necessary capital for building up a great industry. But whatever may be the peculiar qualities that have led to his success, one cannot but admire the noteworthy career of a man who had so few advantages to start with, and has, nevertheless, made for himself a great name as scientific investigator, inventor, and "captain of industry."

Alva E. Brown

VICE-PRESIDENT AND GENERAL MANAGER OF THE BROWN HOISTING MACHINERY COMPANY, OF CLEVELAND

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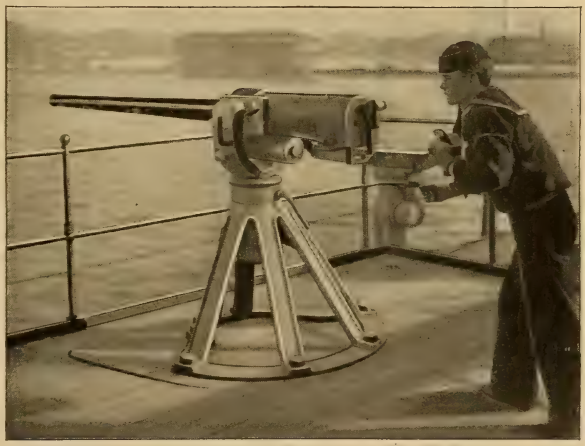
ARMOUR AND GUNS OF FIGHTING SHIPS

By Philip R. Alger, U. S. N.

THE contest for supremacy between guns and armour, which began about forty years ago, has long since been definitely decided in favour of the gun. Great as have been the improvements in the quality of armour, the power of the opposing gun has increased still more rapidly. In 1860 the 4½-inch iron plate was declared invulnerable to any gun afloat; to-day such a plate would be perforated at any distance by the 4-inch gun, and at short range even by the little six-pounder; and when the 17-inch nickel-steel plates were placed on the barbettes of the United States battleship *Indiana* it was known that her own guns could pierce them at any reasonable range. The discovery, ten years ago, that the surface-hardening process was practicable for heavy steel plates for a moment snatched the supremacy from the gun. A 6-inch hard-faced plate defeated the 6-inch gun, which was more than a match for 12 inches of the best homogeneous steel armour, and the 17-inch hard-faced plate seemed likely to be invulnerable. This, however, was only a temporary condition. The invention of hard-faced armour was soon counterbalanced by the invention of the shell cap, and the introduction of smokeless powder at the same time more than doubled the power of the gun. To-day the penetrative power of the largest naval guns, even at extreme ranges, will easily overcome any armour plate ever yet made or ever likely to be made, provided the impact is normal, or nearly so.

The latest development in armour manufacture is the so-called Krupp process. The details of this are kept secret, but it may at least be said with certainty that it is merely an improvement on the Harvey process, and not a radical departure from it. The results



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TO REPEL TORPEDOES

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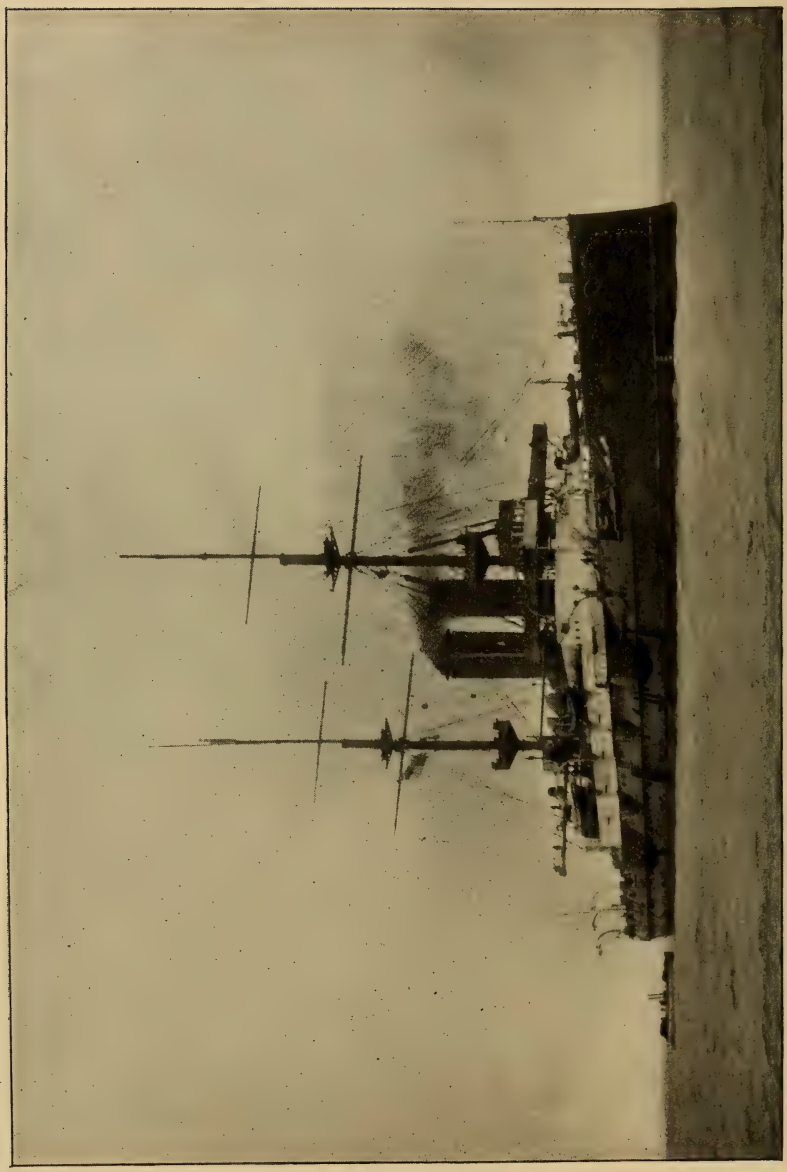

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THE BATTLESHIP "LONDON" OF THE BRITISH NAVY

of tests and examination of the fractured surfaces of Krupp plates show that they have a deeper chill than is ever attained by the Harvey process, and also that they are less liable to crack under shock or when perforated. It is probable that the essential feature of the improved process is the use of a small percentage of chrome as well as nickel in the steel, such an alloy being more susceptible to chilling than is steel containing only nickel. The supercarbonisation of the face, though very likely brought about by the use of gas, is undoubtedly the equivalent of ordinary cementation, and the usual cold water spray is still used to chill the surface.

It has been claimed that the Krupp plates have 20 per cent. more resistance than Harveyised plates of the same thickness, but this refers to resistance to perforation by uncapped projectiles. When the capped armour-piercing shells, now coming into universal use, are fired, the increase in resistance of the Krupp plates is but small. Their freedom from cracking remains a point of superiority, but this is not of great importance in view of the fact that a plate which has accomplished its purpose in excluding one projectile is extremely unlikely to be again struck. However, without regard to the question of how much better Krupp armour is than Harveyised armour, it is a fact that, though its cost is somewhat greater, it has been generally adopted for European navies and will be used on the latest United States armoured ships for all armour exceeding 6 inches in thickness. Now as against this best modern armour, the latest type guns, using capped projectiles, have the following power of perforation at 3000 yards range and with normal impact:—

A 13-INCH GUN DIVISION ON THE UNITED STATES BATTLESHIP "MASSACHUSETTS"

6-inch gun			6¼ inches
8	"	"	10½ "
10	"	"	15 "
12	"	"	19½ "

From this it is apparent that, as already stated, no armour afloat, or in sight, can any longer be relied upon to keep out the projectiles of the heaviest naval guns. But if guns now overmatch all practicable armour, and continue to increase in power, as they have in the past, more rapidly than armour increases in resistance, will they not cause armour for ships to be abandoned and become

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THE RUSSIAN ARMOURED TRIPLE-SCREW CRUISER "ROSSIA." LENGTH, 480 FEET. BREADTH, 68 FEET. DISPLACEMENT, 12,130 TONS

obsolete, as gunpowder drove out of use armour for men?

The argument that armour for ships of war will, in course of time, become obsolete, is usually based upon a supposed analogy of the case of ships with that of men. Since the development of small arms resulted in the abandonment of armour for men, why will not continued advance in the power of ordnance render it useless to armour ships? As a matter of fact, this analogy is a false one, and for two reasons:—

1.—A man's strength is limited, while a ship's carrying power depends only upon her size and may be made as great as we please.

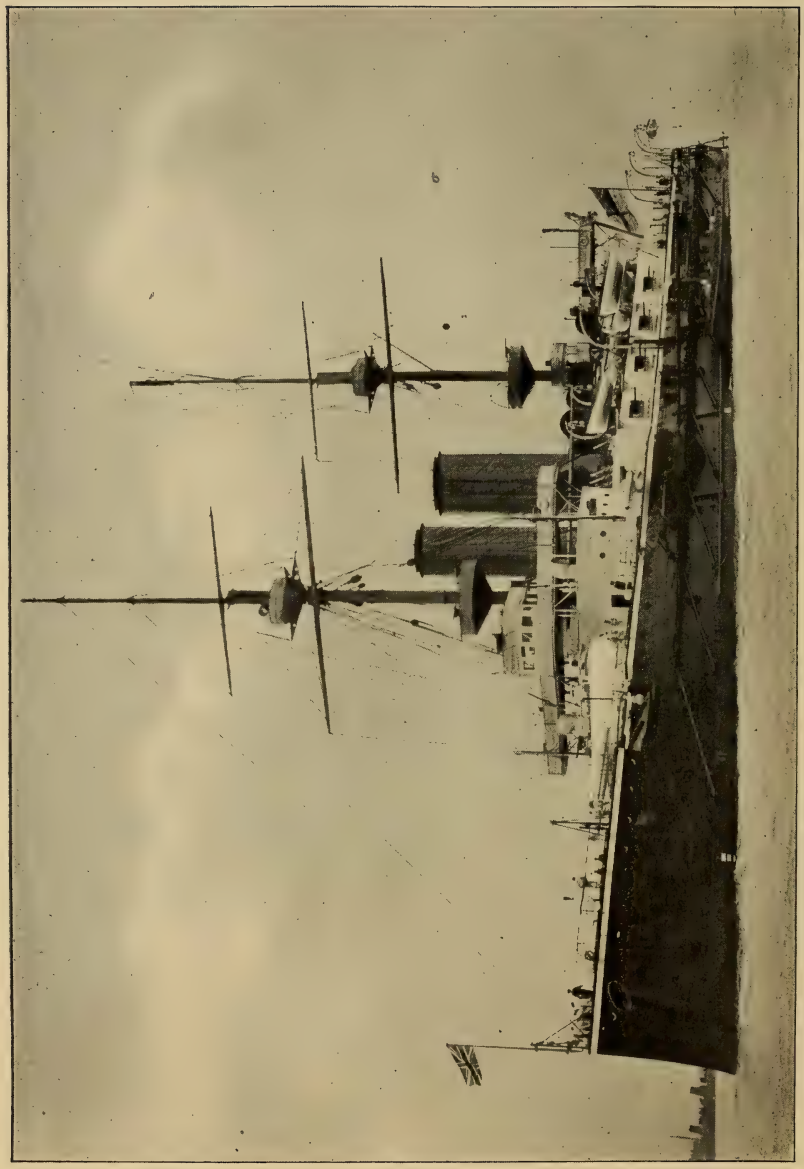
2.—Men, being highly organised animals, are usually disabled by a wound in any part of the body, and consequently must be completely covered with armour to be really protected, while ships, over a large percentage of their area, may be pierced through and through without suffering serious damage, and so need protection only over a few vital parts.

Again, even if the power of guns be so great as to render it useless to attempt to keep out their armour-piercing projectiles from any part of the ship, still an enormous advantage would result from the use of armour which kept out explosive shell. A solid bullet is enough if it hits a man, but a great many solid shot of the largest size may enter a ship without putting her out of action. But even recognising the fact that the best armour will no longer keep out the explosive shell of the heaviest naval guns, a little consideration will show that by keeping out projectiles of the smaller calibres armour renders a service of great value.

Taking, for example, the batteries of the latest United States battleships, four 12-inch, eight 8-inch, twelve 6-inch, twelve 14-pounder, and twelve 3-pounder guns, and supposing the guns which train on both sides to be firing constantly while the others are only half in use at any one time, and assuming the rates of fire to be one round every two minutes for the 12-inch, one round every fifty seconds for the 8-inch, one round every fifteen seconds for the 6-inch, every six seconds for the 14-pounder, and every four seconds for the 3-pounder gun, then a simple calculation will show that of all the projectiles fired in any period of time only 1.1 per cent. will be of 12-inch calibre and only 3.9 per cent. of 8-inch calibre, while 13.1 per cent. will be 6-inch; about 33 per cent. will be 14-pounders and about 49 per cent. will be 3-pounders.

In other words, armour which will defeat the 14-pounder shell, 2 or 3 inches at fighting range, will keep out 82 per cent. of all the projectiles fired by a battleship, and armour capable of stopping the 6-inch shell, say 6½ inches thick, will keep out over 95 per cent. In fact, when we consider that few projectiles will strike normally, and that fighting ranges, now great, are likely to increase rather than diminish, we may safely say that under any probable future conditions armour from 6 to 7 inches thick will keep out fully 95 per cent. of all projectiles which such a battery as that just referred to can fire against it.

When, in 1858, France began to build the *Gloire* and her sister ships, which formed the first squadron of sea-going armoured ships ever seen, it was possible to completely cover them with armour then impenetrable; but the rapidly increasing power of the gun made it necessary for the naval architect to more and more restrict the area defended by armour if he desired to give it complete protection. In the hopeless attempt to secure invulnerability, armour was gradually stripped from other portions and concentrated over the parts considered vital. The restriction of batteries to a few heavy guns mounted in turrets, barbettes, or a central citadel, allowed the thickness of armour protecting men and guns to be greatly increased, with a corresponding reduction in its extent, and at the same time waterline armour was made thicker and thicker and of less and less area, until it almost seemed that the desired invulnerability of armour belt had been secured,—not by its impenetrability, but by the impossibility of hitting it. Of late years, however, there has been



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THE BRITISH BATTLESHIP "IRRESISTIBLE"

a growing tendency to return to the earlier practice of expanding armour over a large area, even at the expense of reduced protection to any one part. Great as are the displacements of the latest battleships, it is not deemed wise to attempt to secure complete protection for any one portion of them at the expense of other parts of less importance; it is recognised that all that armour can be expected to furnish is a reasonable amount of security to what it covers,—a protection to each part proportional to its importance as compared with other parts.

It is necessary, however, to take account of another factor besides the relative importance, in order to determine properly the amount of protection which should be assigned to each of the elements of a battleship. The chances of being seriously damaged should be taken account of as well as the relative importance of damage if it occurs. To put water-line protection first in importance is to say that a ship is in more danger of succumbing to blows there than to an attack upon armament and personnel. But the water-line is an extremely hard thing to hit; a shot which falls even a few feet short ricochets and strikes the ship, if at all, well above the water-line. The armament, on the other hand, occupies the centre of the target, where the hits will inevitably be most in number. It would be unwise to take exaggerated care to make a ship unsinkable and to expose her to easy defeat by attack upon her personnel.

It must be recognised that naval victories are far more likely to result from the destruction and demoralisation of an opponent's personnel than from actual injury to his ships. The Chinese battleships retreated from the battle of Yaloo utterly defeated, yet neither their stability, their machinery, nor their offensive powers had been seriously affected. At Manila Bay, and again at Santiago, American gun fire did not injure the Spanish ships so much as it did their crews, and except for the fires, which an inefficient and demoralised personnel could not control, the matériel would have remained practically uninjured.

Armour, in fact, was devised as a means of protecting the personnel from the effects of shell fire, and in so far as this end has been lost sight of, and attention directed mainly to the protection of the water-line and motive power, an error has been made. The present tendency to thin water-line armour and to devote the greater part of available weight to protecting the guns and their crews is a wise return to first principles.

For convenience in discussion the writer will use the term "hull protection" to mean all armour that protects buoyancy, stability, propelling machinery, and the under-water parts; and the term "gun protection" to mean all that protects the armament and its personnel.

Considering, first, hull protection, it will be found that in early battleships the armour belt was made very heavy, and the protective deck had little importance except structurally, while in more recent designs the weight of armour applied to the deck approaches that of the belt armour. Thus in all the United States battleships, the first of which, of the *Indiana* class, are comparatively new, from 1550 to 1650 tons of armour are allotted to the hull protection, and of this the belt takes from 800 to 900 tons and the protective deck 650 to 800 tons.

In the best modern practice the protective deck is worked from the bottom of the armour belt and its principal function is to exclude the fragments of explosive shell which may have penetrated the belt. The belt itself is intended to exclude all small or medium-calibre projectiles and all large-capacity explosive shell of whatever calibre. Should a large-calibre shell, carrying a moderate bursting charge, perforate the belt, then the protective deck should be strong enough to resist its explosion, which will be caused by its passage through the belt, and to keep out its fragments. In the case of penetration by a heavy projectile without explosive charge, and which remains whole, the deck may suffice to deflect it, but this is not to be

THE ITALIAN BATTLESHIP "RE UMBERTO"

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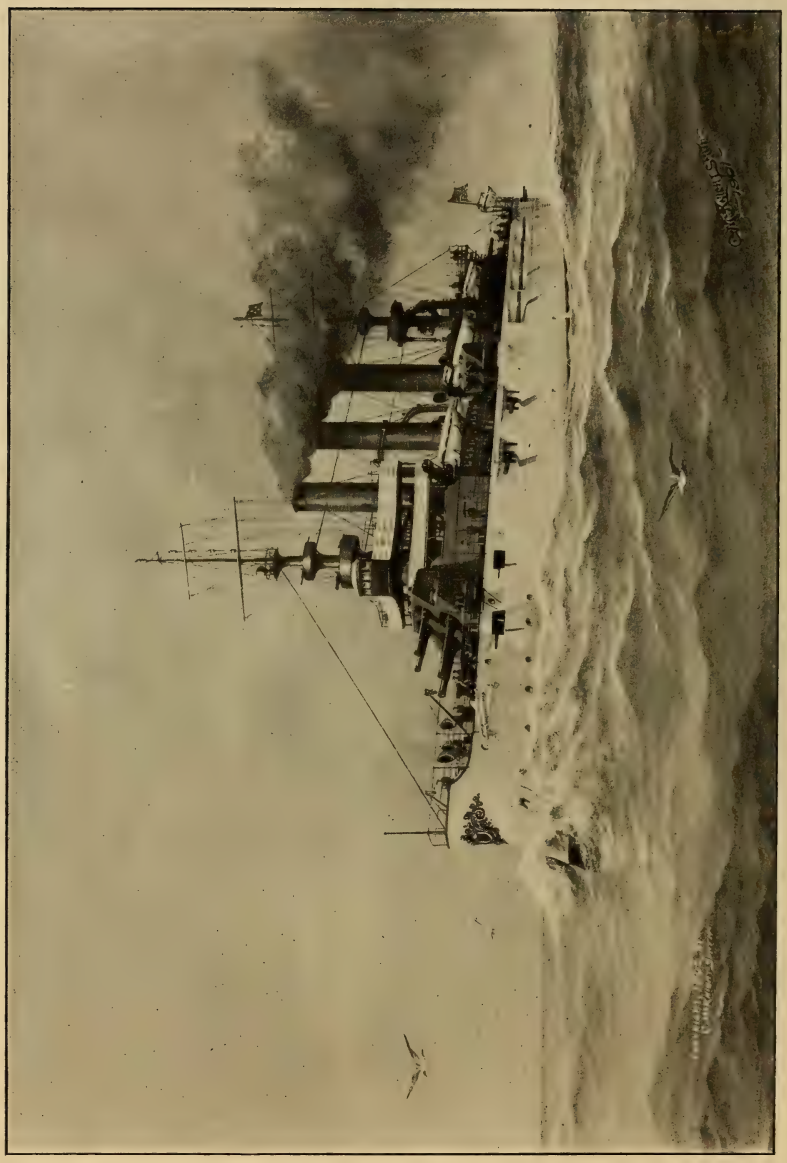
counted upon with any certainty, and must be risked. The latest United States ships have a belt tapering from 11 inches at the top to 8 inches at the bottom over the engine and boiler space, and gradually reduced forward and aft to 4 inches at bow and stern. Their armoured deck is 3 inches thick on the slopes and 1½ inches on the flat.

The British ships *London*, *Bulwark*, and *Venerable* have a 9-inch belt and a deck 3 inches on the slopes; the French *Suffren* has 11.8-inch belt armour and

A 4-INCH GUN AND CREW ON THE UNITED STATES BATTLESHIP "IOWA"

a 2.7-inch deck; the Russian *Retwisan* has a 9-inch belt and a 4-inch deck; and the Japanese *Hatsuse* has a 9-inch belt and a 4-inch deck. All of these, being examples of late designs of battleships of from 12,000 to 15,000 tons displacement, show a very satisfactory general agreement as regards hull protection.

The history of gun protection resembles that of hull protection. At first it was sought to make the one or more heavy gun positions invulnerable, and all available armour weight was devoted to that; but gradually it was recognised that the rest of the battery, which was becoming more and more important offensively, must have a reasonable share of armour protection. The tendency is well illustrated by a consideration of the division of the armour allotted to gun protection in American battleship designs. In the *Indiana* class and the *Iowa* the secondary battery had about 200 tons of armour to protect it, as against from 1400 to 1500 tons for the heavy guns. In the *Kearsarge* and *Kentucky*, and in the *Alabama* class, about 600 tons are devoted to protection or the small, as against about 1200 ton or the large guns; in the *Maine* class about 800 tons go to the small and about 850 tons to the large guns; and, finally, in the *Pennsylvania* class, the rapid-fire guns are protected by 1240 tons, as compared with only 1070 tons allotted to the 8 and 12-inch gun positions. Not only has the percentage of total armour weight given to gun protection been increased of late years, but in the division of that percentage into two classes the share allotted to protect the small guns, or secondary battery, has gradually grown at the expense of that allotted to



THE UNITED STATES BATTLESHIP "NEW JERSEY," NOW BEING BUILT

the heavy or main battery guns, the result of both movements being a great expansion in the area covered by armour and an accompanying reduction in its average thickness.

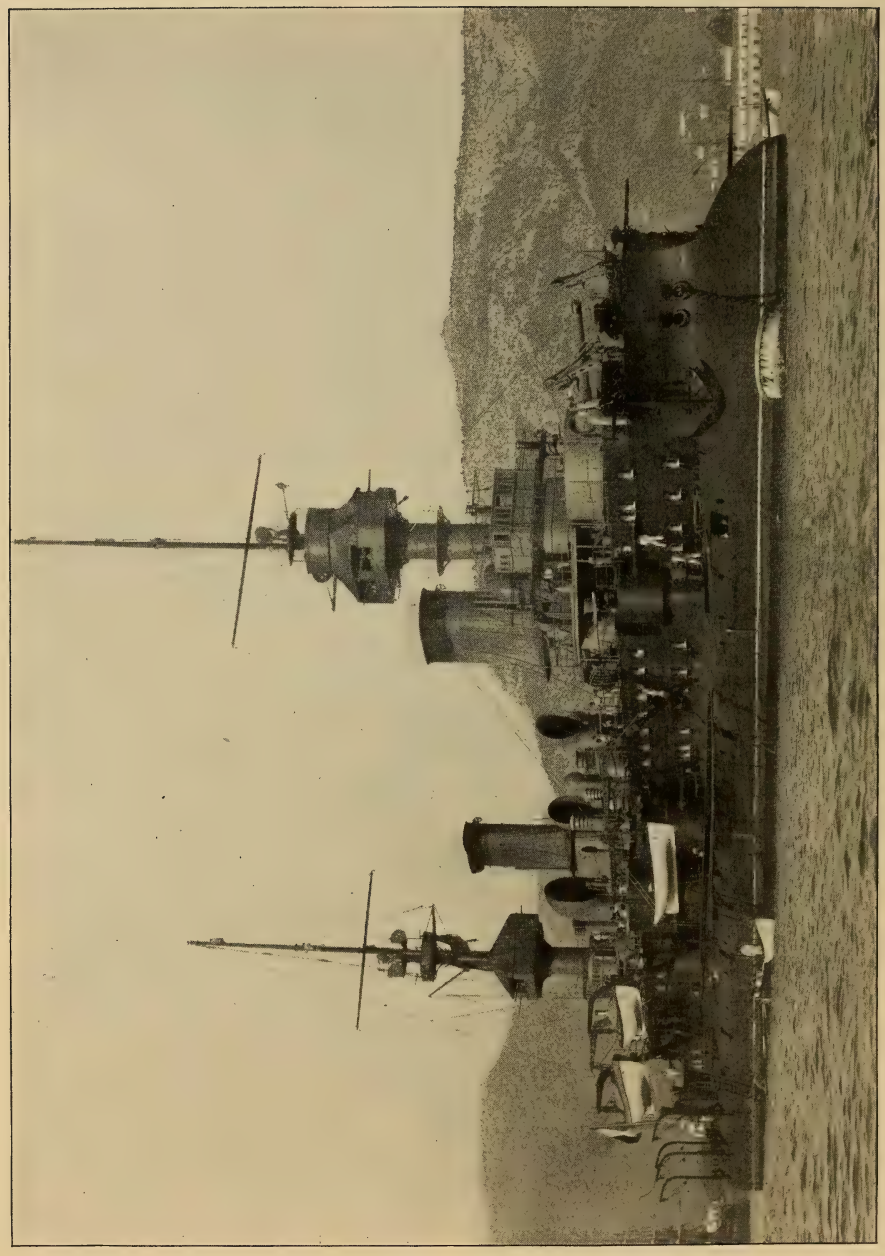
The usual arrangement of the larger rapid-fire guns of battleships to-day is in an armoured casemate between the two heavy gun positions, and it is to their defence that more and more armour is being devoted. At first 4 or 5-inch armour was considered sufficient, but in almost all recent designs the casemate is covered with 6-inch armour. Moreover, the fear of the effects of explosive shell has led to the use of armour for covering the space above the armour belt and below the casemate armour. Thus in the *Maine* class about half the 800 tons of armour devoted to the protection of the 6-inch rapid-fire guns is used to cover the space below the deck on which they are mounted; and in the *Pennsylvania* class a space about 250 feet long and 15 feet high is covered with 6-inch armour, weighing about 1200 tons, to give protection to twelve 6-inch guns. It is not considered enough to completely enclose the deck on which the 6-inch guns are mounted with armour; but the deck below, although it contains little of importance, must be equally protected lest the free entry there of explosive shell produce serious destructive effect upon the deck above.

It seems to be doubtful if the result of this disposition of armour is a security commensurate with the expenditure of weight. Six inches of armour are by no means a sure defence against large-calibre shell carrying explosive charges, and one such shell, especially if it entered anywhere near fore and aft, might well put half, or even more than half, the 6-inch guns out of action. It is true that such a raking effect is usually guarded against by partial transverse armoured bulkheads between the guns, but the time has come when complete isolation of all guns, either singly in closed armoured casemates or in pairs in turrets, is a practical necessity.

Open battery decks, giving central control of all the guns, have many advantages, but the use of smokeless powder has minimised these by making individual firing effective under all circumstances, and they must be given up in order to gain greater protection against the ever-increasing destructiveness of gun fire. If the 6-inch guns, as well as the larger ones, were mounted in pairs in turrets, each with enough armour to protect it from anything but the direct hit of a large-calibre projectile, then no shell could do more than put one pair of guns out of action, and not only would the material damage done by a successful shell be localised, but so also would be its moral effect.

The weight now generally devoted to protecting secondary battery guns by means of side plating would furnish them with turrets and barbettes of equal thickness, and, at the same time, armour the ammunition hoists, smoke stacks, and uptakes, which are now protected by the side armour above the main armour belt; and should the turret system not be approved, the guns may be equally well protected from the effects of large-calibre shell bursting in the battery deck by being each placed in a closed compartment, armoured in the rear as well as outboard. More certain destruction of the entire contents of any compartment entered by a shell would result, but so also would such destruction, with accompanying flames, smoke, fumes, and the demoralising effect of the sight of killed and wounded, be equally localised and confined.

The foregoing discussion has had special reference to the class of battleships, and there remains something to be said of the armour of cruisers. It would be difficult to define what an "armoured cruiser" is more clearly than by saying that it is an armoured ship in the design of which both gun power and armoured protection have been sacrificed to obtain great speed and coal endurance,—unfortunately sometimes to obtain only the former. In a first-class battleship from 25 to 28 per cent. of the displacement may be devoted to armour and 10 per cent. to the ordnance outfit; while in armoured cruiser design armoured protection would not be likely to reach 20



THE FRENCH TRIPLE-SCREW TURRET SHIP "MASSÉNA." LENGTH, 360 FEET. BREADTH, 66 FEET. DISPLACEMENT, 11,900 TONS. I. H. P., 12,600

per cent., and the ordnance outfit would be only about 6 per cent. of the displacement.

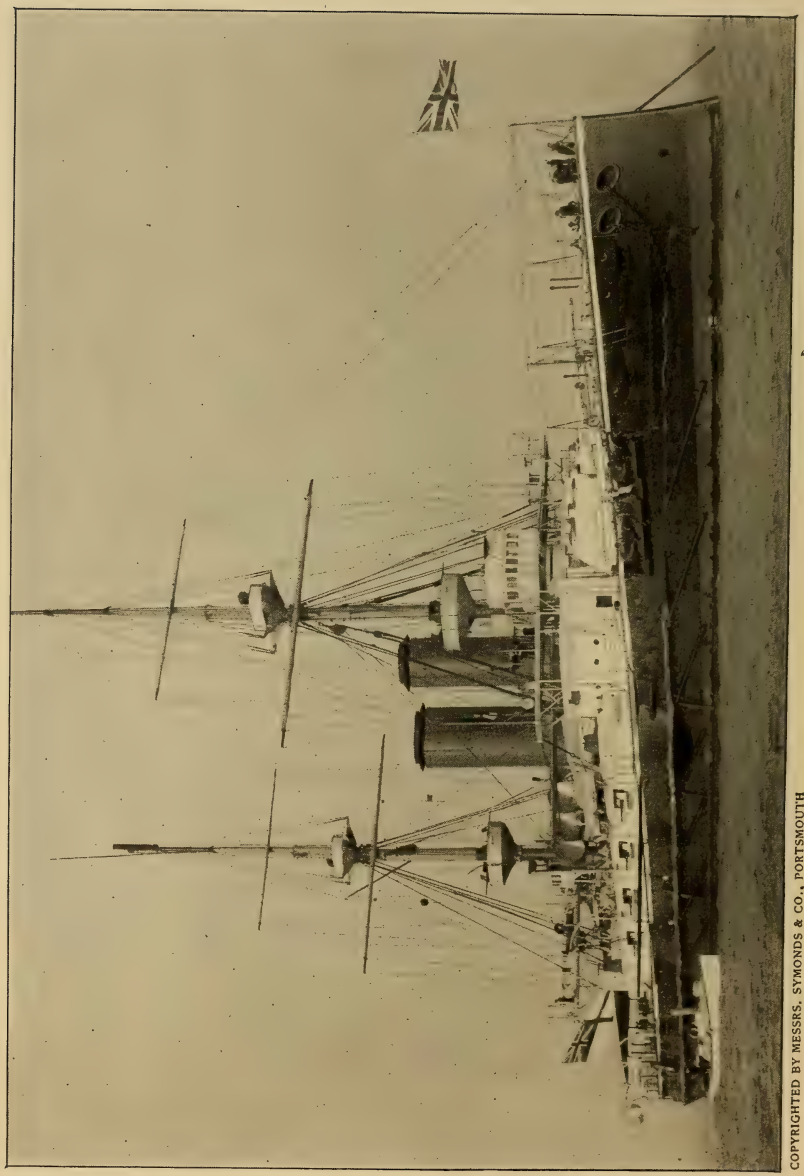
In the recent United States designs of armoured cruisers, the *West Virginia* class, a decided tendency is shown to approach the latest battleship designs. They have a complete belt; a protective deck worked from the lower edges of the belt; an armoured casemate above the belt, covering two decks, on the upper one of which are mounted ten 6-inch guns; and an 8-inch turret at each end. Their total armour weight, exclusive of the protective deck, is 2219 tons, as against 3690 tons for the *Pennsylvania* class, and there is no practical difference in the arrangements of the armour in the two cases, the only distinction being that the thickness of the armour is somewhat less on the armoured cruiser than on the battleship.

Without meaning to condemn armoured cruisers as a class, it may fairly be said that these ships approach too closely, in size and cost, to first-class battleships to justify their relative lack of offensive and defensive power. Speed has some value, and coal endurance a much greater value, but neither counts in actual fighting, and neither compares in importance with fighting efficiency. It is of the first importance that a ship of war shall be able to exercise a full power of offence and defence within the circle of which she is the centre. Secondary to this comes the capacity to transfer that power from one point to another with certainty and rapidity. Of course, speed is useful as a means of escaping or of forcing an engagement, and as giving the power of rapid concentration or of striking suddenly at a distant object; but when the moment of battle arrives, superiority of speed will weigh as nothing in comparison with superior armament.

There are those who look upon such ships as the *West Virginia*, of high speed and carrying only guns of medium size, as the coming type of battleship, but they greatly undervalue heavy guns and thick armour. Hardly by any possibility even could the *West Virginia* whip the *Indiana*, though more than 3000 tons bigger and of eleven years' later design. However many 6 and 8-inch guns the former might carry, and however skillfully they might be used, they could hardly do more than demolish the unessential parts of a ship like the latter; the *Indiana's* 13-inch guns would almost certainly remain intact and sooner or later destroy her opponent. Should light guns and thin armour really come into vogue for the heaviest fighting ships, a single 10,000-ton ship, specially designed to meet them, would be able to whip a whole squadron of such.

The experiences of late naval wars have given birth to two theories which are to the last degree fallacious and destitute of rational foundation. The first of these theories discredits the torpedo-boat; the second ascribes to rapid-fire guns an important and even decisive part in future actions between armoured as well as unarmoured ships. No greater mistake can be made than to rely upon anything else but the heavy guns of a battleship to defeat another such ship, if the latter is willing to fight.

You can utterly destroy and sweep away the whole secondary battery of a ship like the *Kearsarge*, or the *Alabama* even; but while she remains afloat and with her heavy gun turrets intact, her offensive power as against another battleship is practically undiminished. The only thing to be feared in such a situation is the demoralisation of the crew due to the killing and wounding of so large a percentage of their number, but this should rather tend to make us question the advisability of exposing so many men to destruction in order to man guns whose fire cannot injure any vital part of one's opponent except by the luckiest chance. There is good opinion in favour of sending the crews of all the small rapid-fire guns below the protective deck and keeping them there during an action between battleships, and though the writer would not advocate pursuing the same course with the entire secondary battery, the arguments in favour of so doing should at least lead us to recognise the comparatively unim-



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THE BRITISH BATTLESHIP "FORMIDABLE," A SISTER SHIP OF THE "IRRESISTIBLE"

portant part which that battery must play in such an action.

This leads us to the question of the calibre and arrangement of guns best suited to a battleship. It is, of course, essential to carry some guns of sufficient power to pierce the armour which covers the vital parts of possible opponents, and this led, some years ago, to the construction of guns of 120 tons weight and 17-inch calibre. Of late years, however, the tendency has been towards smaller guns having such chamber capacity and length of bore as to equal or exceed in power older guns of greater size and weight. Great Britain no longer arms battleships with her 16¼-inch gun, nor even with the 13½-inch, but with the 12-inch, and some Continental powers have even built battleships carrying no larger guns than the 10-inch. The earlier American ships carried 13-inch guns, but on the latest ones a 12-inch gun, which, with its mounting, weighs nineteen tons less than the old 13-inch gun, and whose ammunition weighs 400 pounds less per round, but which exceeds in muzzle energy and penetrating power the 13-inch gun, has replaced the latter.

The question, then, naturally arises, why not continue further in the same direction? Having replaced a 13-inch gun by a higher-powered 12-inch, why not replace the latter by a still higher powered 10-inch gun? A 10-inch gun with 4000 feet per second muzzle velocity would have greater energy than the present 12-inch gun, and such a gun can, doubtless, be made, and even with a saving of weight in the total installation. In fact, we have seen exactly this same line of advance followed in the development of the modern small arm. From the days when the calibre was nearly an inch till the present time when about a quarter of an inch is generally held to be the most advantageous size, progress has consisted in a constant decrease of calibre without a corresponding decrease of chamber volume and powder charge, the result being increasing muzzle velocities. The bullet of the 45 calibre weighs four times as much as that of the 6 m.m. rifle; but the cartridge of the latter is almost as large as that of the former, and the muzzle velocity has risen from 1200 to nearly 2600 feet per second.

There is an important difference between the two cases, however. Flatness of trajectory is equally of value in fighting between ships at sea and between men on shore, on account of the resulting increased danger space. Reduction of weight per round of ammunition, while most important to the soldier, is still of great advantage on the war vessel. But the one disadvantage of the small calibre, its loss of destructive effect, tells against it in naval warfare far more than in land fighting. Man is so highly organised an animal that, as a rule, any wound will put him out of action; but a ship may be struck again and again, without having either its offensive or defensive powers materially reduced.

If rapidity of fire were inversely proportional to weight of projectile, the process of reducing calibre could be advantageously extended much further than it now can be, but there would be no practical difference between the rates of fire of 10, 12, and 13-inch guns of the same power, and while a great deal of weight would be saved by substituting a 10-inch gun of equal power for the present 13-inch, the decrease of projectile weight from 1100 to 500 or 600 pounds would not be compensated for by any material increase in the rate of fire, and the slight increase in the percentage of hits resulting from the flatter trajectory of the smaller calibre would by no means make up for the vastly greater destructive effect of the larger shell.

In the small arm and machine-gun field, where it is really better to wound a man than to kill him, and where any man who is hit, whether by a small or by a large bullet, is almost certainly put out of action for the time being, the greater percentage of hits due to the flatter trajectory is important, and the increase in the number of rounds carried by the soldier, due to their less weight, is a decisive reason in favour of the smallest practicable calibre. In the field

THE 15,000-TON BATTLESHIP "HATSUSE," THE LATEST ADDITION TO THE JAPANESE NAVY.

of heavy naval guns the destructive effect of each projectile becomes a matter of great importance, and this consideration puts a limit to advantageous reduction in calibre.

While, therefore, the future may see some slight further decrease in the calibre of the main battery guns of battleships, it seems unlikely that the present American and British practice of using the 12-inch gun will be abandoned.

As regards the number and arrangement of the guns of battleships, there is now almost universal agreement that the main battery should consist of two pairs of heavy guns in turrets, on the centre line, one forward and one aft; but what the remainder of the battery would better be is much more doubtful. One important consideration is this,—in modern battleship designs weight of battery counts for little as compared with space for good gun positions. If the 5-inch rapid-fire gun could pierce any secondary armour, we still could not afford to have 5-inch guns only as a secondary battery, because good positions cannot be found for enough of them. We would still use 6-inch guns, because we can mount as many 6-inch as 5-inch, and while an equal weight of 6-inch guns would give less, an equal number of 6-inch guns would give much the greater volume of effective fire.

This argument seems to lead logically to the use of a still larger calibre, say the 7-inch instead of the 6-inch; but the objection to that is that when you go beyond the 100-pound 6-inch shell two men are required to handle the heavier projectile, and rapidity of fire is at once considerably reduced. If the 6-inch gun were effective against all secondary armour, it would hardly be questioned that this calibre is the proper one for the secondary battery of a battleship. It was because the 6-inch gun was known to overmatch 5-inch armour, and because it was supposed that improved 6-inch guns would also overmatch the 6-inch armour then coming into use as the secondary armour of battleships, that the batteries of the American *Alabama* class were constituted as they are, with no guns between the 12-inch and 6-inch calibres.

But is the 6-inch gun, even with its greatly increased power, a match for the 6-inch armour now being used on battleships, under service conditions? Its armour-piercing shell can just about get through a 6-inch plate of the best quality if it hits within about 10° of normal at 3000 yards range; at greater ranges, or with a greater angle of incidence, the 6-inch armour will keep it out. Moreover, apparently as a reply to the new high-powered 6-inch guns, Great Britain has already decided upon an increase of secondary armour to 7 inches. Clearly, the 6-inch gun can no longer be considered as effective against the secondary armour of the future battleships and we must replace it by a still more powerful gun.

Two plans have been proposed for future American battleships. One contemplates the use of a new calibre, the 7-inch; the other, the enlarged use of the 8-inch gun. Which is the better plan must largely depend upon whether the rate of fire of a 7-inch gun is greatly less than that of the 6-inch gun or not. A 7-inch gun has been built, and its trial in comparison with the 6 and 8-inch guns should determine this point. If the rates of fire of the 7 and 8-inch calibres are found to be not greatly different, while there is marked superiority, in this respect, of the 6-inch over the 7-inch, there can hardly remain any doubt as to the advisability of going at once from the 6-inch to the 8-inch gun and not introducing a new calibre into the service.

The question, however, is somewhat complicated by that of the best arrangement of the new batteries. One might favour the 7-inch gun if it is to be mounted in broadside, as the 6-inch guns now are, and yet prefer the 8-inch gun if the turret system of mounting is to be adopted.

As a matter of fact, it has been decided, for the present, to adopt as a battery for the next United States battleships four 12-inch guns and eight 8-inch guns in turrets, and twenty 7-inch guns in broadside, and though

it may be questioned whether 12-inch and 8-inch guns only would not be better, one thing at least is certain, and that is that such a battery will be far and away the most powerful that has ever yet been placed on any warship.

It is very interesting to trace the development of the modern battleship from its first form,—to see the gradual restriction of the armoured area and of the number of guns till two or four very large guns behind very thick armour constituted their whole offensive power, —to see the first beginning of secondary batteries in the form of a few Hotchkiss revolving cannon or 1-inch Nordenfelts, intended solely for use against torpedo-boats, and their development to the present 6-inch rapid-fire batteries which weigh more and occupy much more space than do the main batteries,—to see the gradual expansion of armour, made necessary by the increased extent and thickness of the armour devoted to protecting secondary batteries, forcing us to return to the use of only large guns in turrets and small, rapid-fire guns for defence against torpedoes. And yet what an enormous advance, both in offensive and defensive power, has been made! Let a comparison between the battleship of to-day and that of twenty years ago bear witness! The course of this development has certainly not been in a straight line; but neither has it been in a circle, finally to end where it began; rather may it be likened to a spiral whose widening coils, though seeming to return upon themselves, give a gradual but certain progression from the starting point.

ELECTRICITY IN A MODERN SHIPYARD

THE PLANT OF THE NEW YORK SHIPBUILDING COMPANY, AT CAMDEN, N. J.

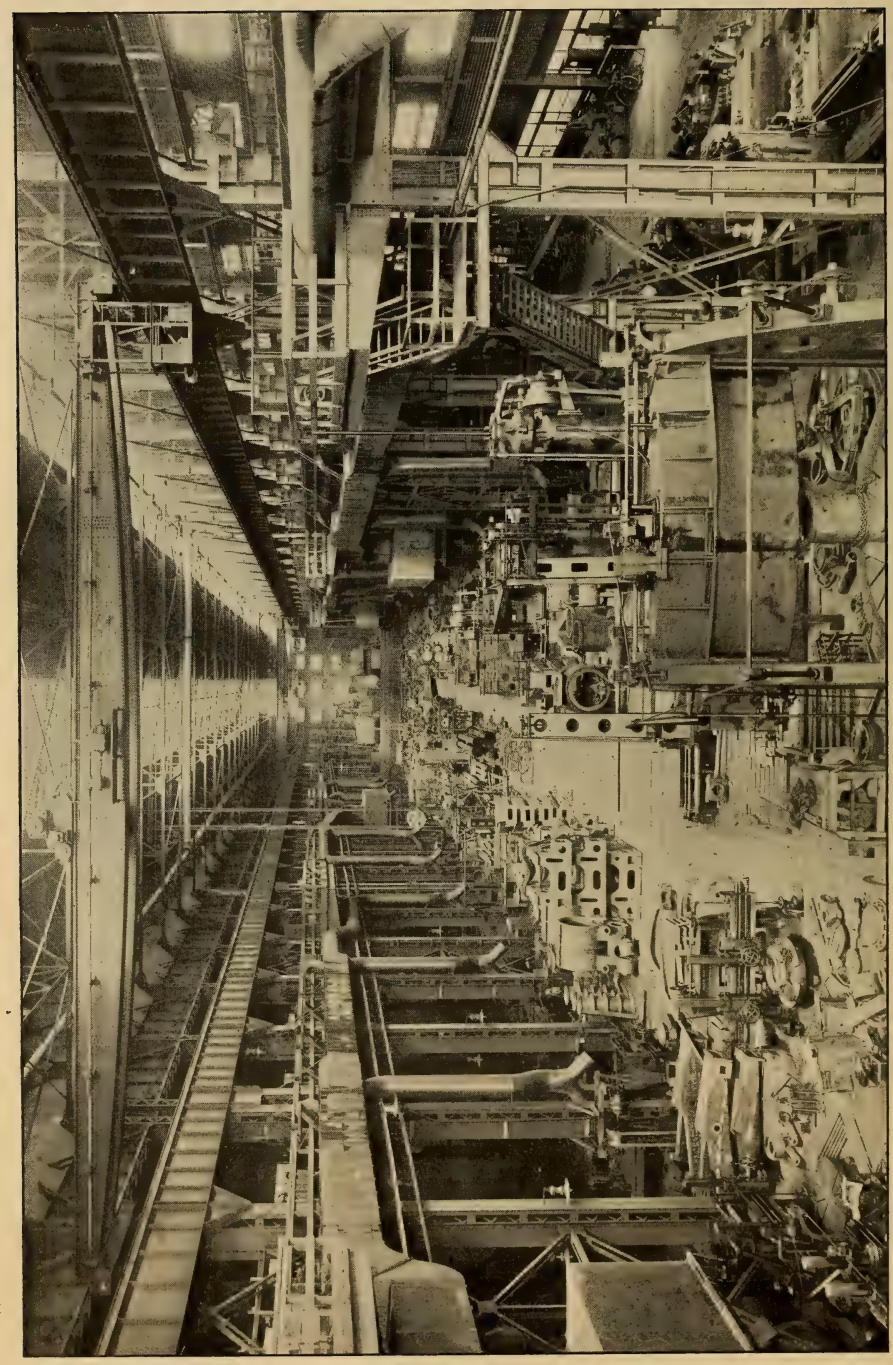
By J. B. O'Hara

WHERE the conditions in manufacturing have not been such as positively to compel the development and use of means for quickening production and cheapening cost, and where the introduction of thoroughly modern methods would have involved heavy expense, it is perhaps not astonishing that the "scrapping" process has not been adopted with great zeal. This has been true in great measure of the shipbuilding industries on both sides of the Atlantic, though there are notable exceptions of old-established plants in which some of the best improvements have been quickly turned to account.

In the case of an entirely new shipyard, however, it might be expected that the plant would be laid down along wholly modern lines, and that, in the matter of power equipment, extensive use would be made of electric transmission and driving. A splendid example of American enterprise of this kind is found in the plant of the New York Shipbuilding Company, at Camden, N. J. This installation is modern in every respect; all the buildings have been put up within the last three years; the equipment is entirely new; many of the machines were designed especially for these works, and the entire organisation, plan of operation, shop methods, etc., were worked out to meet the special requirements of this concern. It was a large undertaking, but the company had the experience of older establishments to guide it, and, moreover, the management, under the leadership of Henry G. Morse, included in its organisation many of the ablest engineers of the country, all of them especially qualified to solve the problems of their respective departments. The electrical features were under the direct supervision of Prof. W. L. Robb, who acted as consulting electrical engineer for the shipbuilding company.

An idea of the originality, extent and completeness of the company's system and methods may be gained when it is explained that, with the exception of the power plant and the joiner shops, the entire establishment, which gives employment to 4000 men, is under one roof; that the material which enters the plate and storage rooms at one end of the yard does not leave the building until it goes out as a part of the completed ship for which it was intended, when the vessel is ready to enter service; that there are installed in one main building and under one roof all the material and machinery necessary for the construction of the largest ship known to commerce, and that eight sets of ship ways, built upon masonry foundations, covered by roofs of steel and glass and spanned by cranes up to 100 tons lifting capacity, are practically as much a part of the immense main building as the boiler shop or machine shop.

About 3600 feet of river frontage, a machine shop with four acres of floor space, and a storage house for 20,000 tons of plates and shapes, are features of the works. The plant has been laid out to achieve economical results in the beginning—not merely to become economical with the growth of business.



A VIEW OF THE MACHINE SHOP OF THE NEW YORK SHIPBUILDING CO. AT CAMDEN, N. J. WITH THE SYSTEM OF INDIVIDUAL ELECTRIC DRIVING OF THE MACHINE TOOLS, THE FREEDOM FROM OVERHEAD SHAFTING AND BELTING IS CONSPICUOUS

It can be extended and enlarged at will, as extension means little more than duplication of the existing parts; but, in its present condition, it is complete in every part, and may rightly be considered a finished plant.

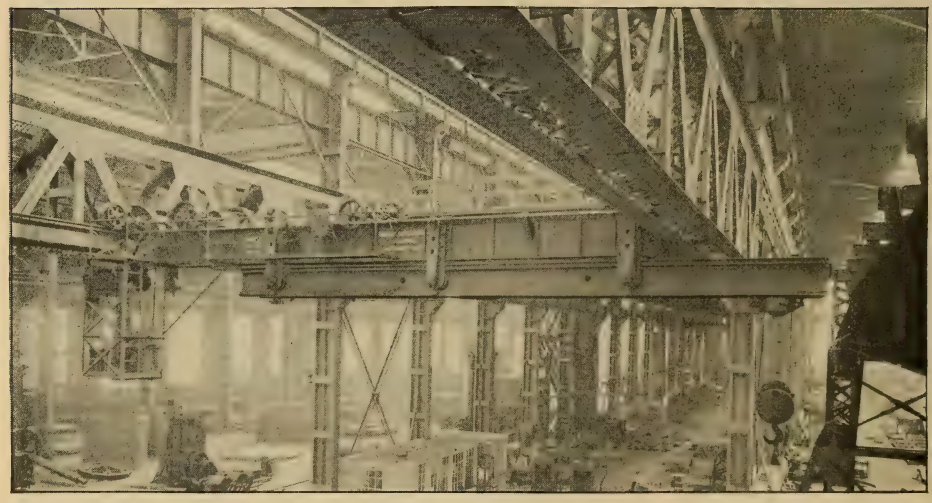
The organisation and the form and arrangement of the shops and departments contributed largely to the successful development of the project to introduce electricity in the operation of the plant on a larger scale than had ever before been attempted in shipbuilding. It was determined to depend mainly upon this form of power, and to utilise it in the operation of many machines hitherto driven by compressed air, steam, or hydraulic power. An elaborate system was, therefore, worked out, providing for the generation, transmission, and distribution of electricity on a large scale and in the most economical manner. As has already been mentioned, the power house is entirely distinct from the main building, and the joiner shop is likewise entirely isolated; thus, by keeping the steam plant in a separate building, the company has succeeded in removing as completely as possible all danger of fire. All the power used in the works,—compressed air, hydraulic, and electric,—is generated in this power house, and thence transmitted to the several departments for use.

The most noteworthy feature of the power house equipment is the electrical plant, and this is particularly interesting because of the unusual character of the apparatus employed. In the selection of the system to be installed, the company's engineers were governed entirely by the special character of the service to be performed and by the local conditions that had to be met. It had been determined to employ direct-current enclosed arc lamps for illuminating the yards and shops, direct-current motors for operating cranes, and alternating-current motors for driving machine tools; consequently, provision had to be made for generating both direct and alternating currents, and to meet these requirements double-current generators of the type shown in the view of the power house on page 122 were adopted. They comprise two direct-connected, 500 kilowatt Westinghouse generators delivering current at 250 volts and 3000 alternations, when operated at 120 revolutions per minute.

These machines resemble standard rotary converters for transforming alternating current into direct current or direct current into alternating current, but were modified in this case to be operated by mechanical power as generators, delivering both direct and alternating current at the same time, and with very satisfactory results. In appearance these double-end generators resemble direct-current generators, with the exception that collector rings are added. An important feature of these generators is that the proportion of alternating and direct current delivered is regulated by the demands upon the machine; thus, when there is a heavy demand for alternating current the proportion may be five-eighths alternating current and three-eighths direct current; or, when the demand for direct current is greater, the proportion is automatically reversed.

In the plan of the yards and the arrangement of the several departments an elaborate system of electric cranes was devised, including transfer tables, by means of which it is possible to put all departments in communication, so that from the time the material enters the yards until it leaves them as a part of the ship it is handled entirely by cranes. The material is received on the yard railway, which comprises about six miles of track within the company's enclosure, practically none of which, however, enter the buildings. A wing of the building is devoted to the unloading of cars, and tracks have been laid in this extension for a distance of 500 feet. Experienced shop managers will appreciate the advantage of an arrangement which makes it unnecessary to cut up the floors with tracks, take up valuable space with runways, and obstruct the building with freight cars, besides obviating the inconvenience of having locomotives enter the buildings. The receiving station for material is

AN 88-FOOT SPAN GANTRY CRANE, WITH LIFTING MAGNETS FOR HANDLING PLATES



ONE OF THE EXTENSION-ARM CRANES

the plate storage shed at one end of the yard, and at right angles is the main building, which, under one roof, and that 150 feet above the ground, includes the machine shop, boiler shop, blacksmith shop, frame shed, plate shop, general storehouse, brass shop, pipe shop, copper, tin and light plate shop, mould loft, building ways, and outfitting slip. These have a floor space of eighteen acres, and are lighted by four acres of skylights and two acres of window surface. When the cars are unloaded in the wing the material is taken by a twenty-ton gantry crane to the place assigned it, the plates being arranged on end in racks, as shown in the view of the plate shop on the opposite page. As the plates are required they are picked up by the crane and carried to the straightening or bending rolls or other tools at the end of the shed.

The large gantry crane shown on this page operates in the yard just outside of the building, and, entering the

wing, travels the entire length of the storage plate shed, crossing the end of the boiler, angle, and plate shops. It has a span of 88 feet and a lift of 22 feet. There are two ten-ton trolleys equipped with chain hoists and lifting magnets, and it can span two freight cars lengthwise. Each trolley is provided with a 25-horse-power street car motor to lift the full load 20 feet per minute, and a 2-horse-power enclosed crane motor to traverse the trolley along the bridge which is moved along the runway by two 25-horse-power street railway motors operated in series-parallel. This gantry is really a feeder for the extensive system of thirty-five electric overhead travelling cranes in the shops, ranging in lifting capacity from 5 to 100 tons and operated by motors aggregating 2000 horse-power.

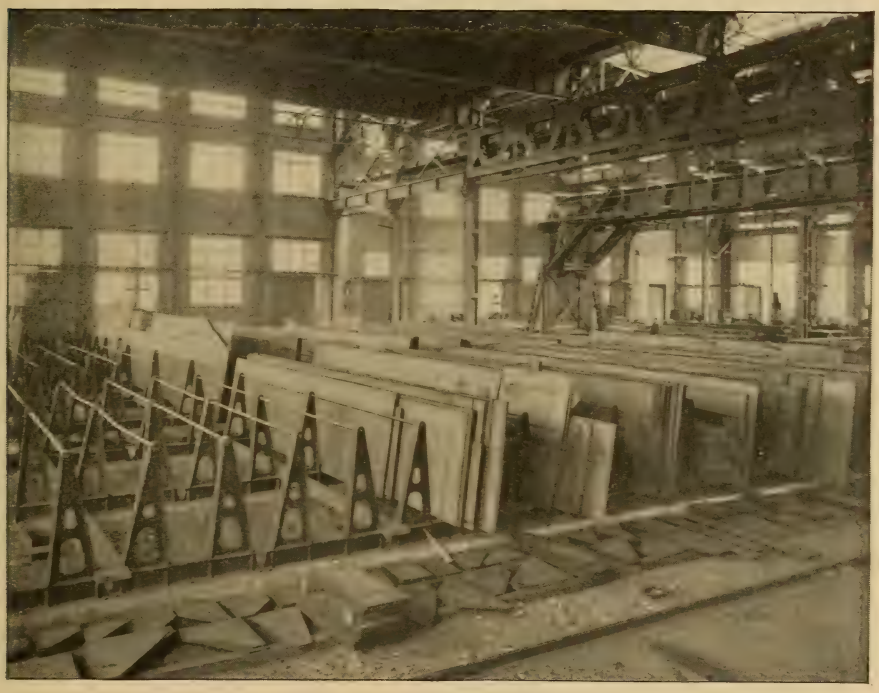
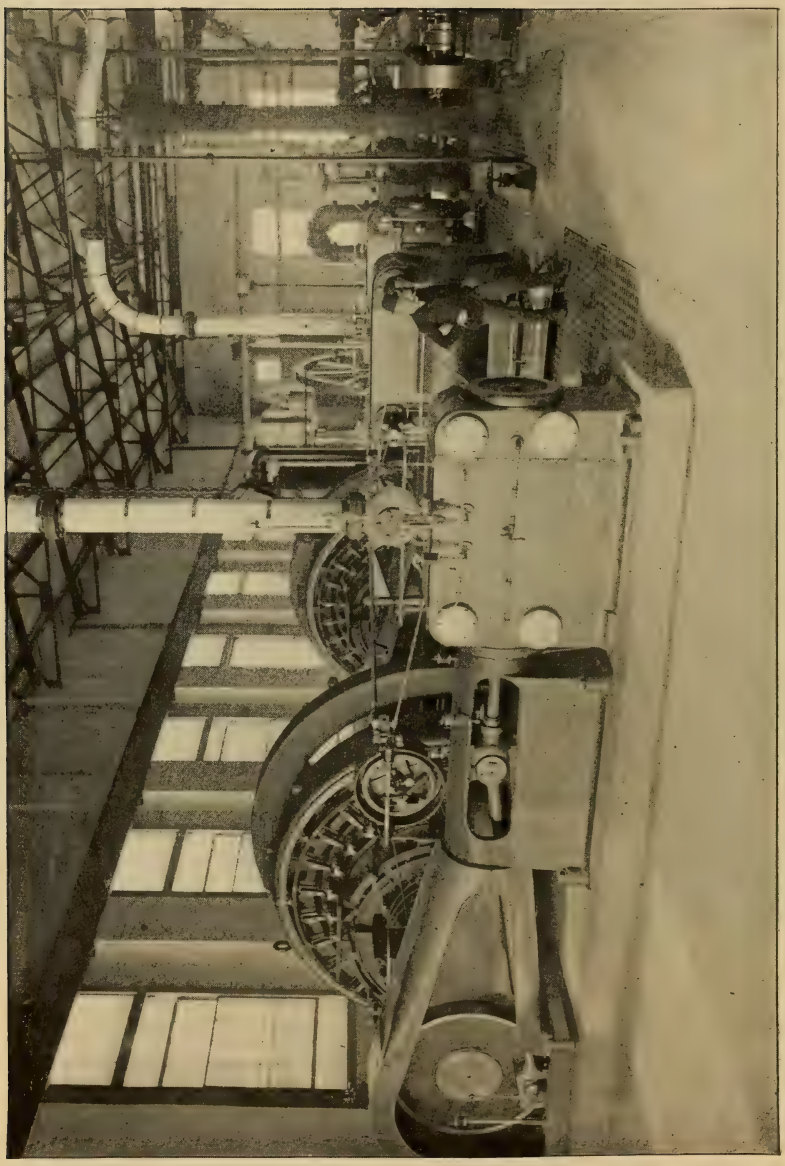


PLATE RACKS WITH OVERHEAD CRANE SERVICE

The huge 100-ton crane within the shop is carried on a span of 121 feet and its field of operation covers the machine shop, ways and slip, so that it may be employed to lift an engine or boiler bodily from the machine shop and deposit it in a vessel under construction, either on the ways or afloat. The crane has two trolleys, each capable of lifting fifty tons at 8 feet per minute, and each provided with a 50-horse-power street railway motor. The height of the lift is 115 feet, and each load is carried by eight parts of wire rope. Each trolley is traversed in the bridge by a 7½-horse-power enclosed crane type motor. The bridge, with its 121-foot span, is carried upon 24-inch steel-tired bridge wheels in equalising trucks. Two 35-horse-power street railway motors with series-multiple controllers are provided for its travel.

Each of the smaller cranes has its own field of operation, and an original type has been installed, which, by means of an extension arm, is able to deliver and receive material from another crane without rehandling; in other words, it can reach beyond its ordinary field of oper-



A VIEW OF THE POWER-HOUSE INTERIOR

ations into a parallel field and thus transfer material from one field to the other.

Cranes in the department handling plates are equipped with powerful lifting electromagnets, controlled by the operator in the cage. The advantage of this arrangement is that instead of having to employ half a dozen labourers to lift the plate, with crowbars while a chain is being slipped underneath and then to go with it to its place of deposit and release the chain by a similar process, only one man is required besides the operator. The latter brings the lifting magnet over the plate, turns on the current, and the plate, which thus becomes the armature of the magnet, can be lifted and carried to any place in the shop, and then instantly released by the turning off of the current. Sometimes several plates are picked up at the same time, and the operator by quickly opening and closing the switch can drop them one at a time, the residual magnetism in the lifting magnets holding the plates nearest them. Of course, considerable skill is required on the part of the operator to perform this feat.

An interesting part of the crane equipment is found in the extension-arm cranes. By means of the extension arm the crane may be made to pick up a load from an adjoining bay, return the arm with its load to a safe position under its own bridge, and carry the load along the runway without danger of striking any of the runway columns. An important feature of the crane is that when the extension arm is projected, the bridge cannot be traversed along the runway until the arm is drawn back to its saef position. This is accomplished by using the same motor for traversing the bridge and projecting the arm, and having special clutches to throw out one movement when the other is thrown in.

Among the men at the Camden yard the extension-arm cranes are commonly called "rubber necks." The seven and one-half-ton cranes are of 38 feet 4 inches span, and have a lift of 26 feet. The hoisting is accomplished by a 25-horse-power street railway motor, the trolley is traversed within the bridge by a 7½-horse-power enclosed crane-type motor, and the bridge travel is performed by a similar machine, which, as already explained, is also arranged to operate the extension arm.

It was mainly in the adoption of electricity for the operation of all classes of machinery and tools on a more extensive scale than had ever before been attempted that the New York Shipbuilding Company especially departed from the practice of other yards. Instead of confining its electrical equipment to conventional lines, it extended its field so as to include practically every form of apparatus employed in the building of a modern ship. Shafting was almost completely eliminated throughout the works. A few of the smaller machines are grouped under the gallery in one end of the machine shop, and some in the joiner shop and tool room, and they are driven from shafting operated by motors, but these are exceptional cases, as will perhaps be better realised when it is stated that there are 312 separate motors employed in driving distinct machines. These motors range from 2 to 50 horse-power, and many of the applications are innovations in shipbuilding practice.

It is in the field formerly occupied by steam and hydraulic power that the electric motor has made its most distinct advancement. Hydraulic power often displaces steam power, because the power delivered by a steam engine is necessarily variable through each stroke, while that delivered by the hydraulic ram or press is constant within the limits of its useful range. The steam engine cylinder receives steam during only a portion of its stroke, and for the remainder of the stroke the energy delivered to the piston is constantly falling. With the electric motor this variation does not exist, and when the supply service is properly arranged, the motor selected of proper size, and other conditions are favourable, the energy delivered by the electric motor is as uniform as that delivered by the hydraulic press, and all danger of the system being crippled on account of frost in the busiest time of the year is eliminated. A glance at the illustration on page 118

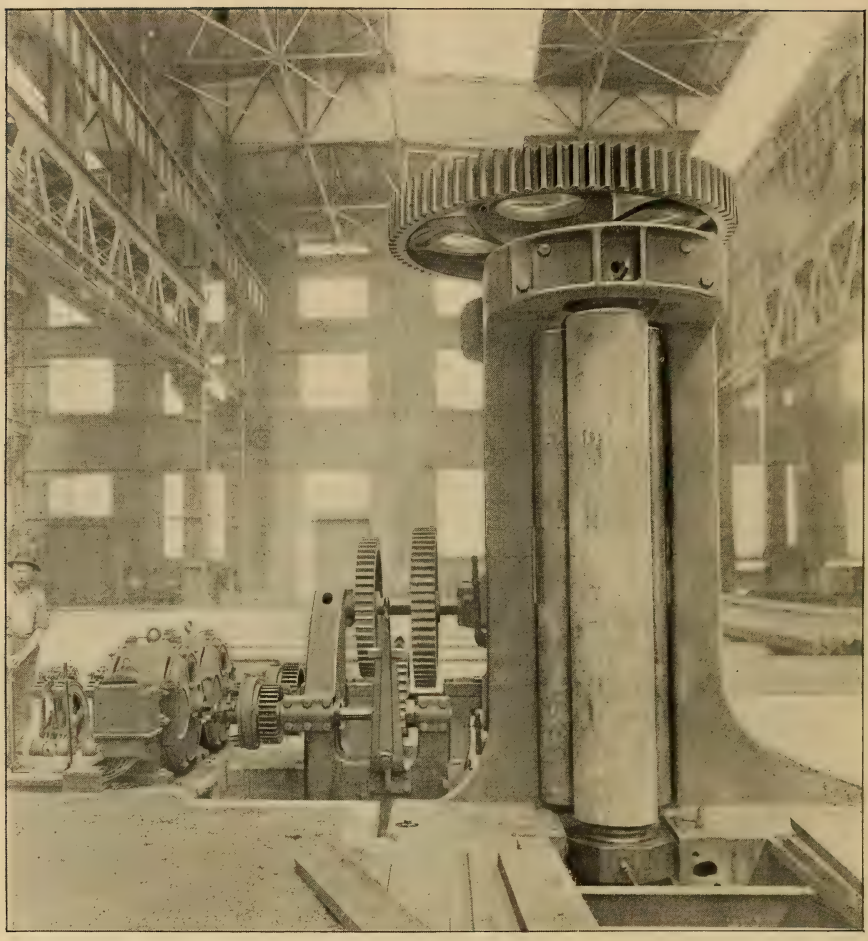


PLATE BENDING ROLLS BUILT BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA

of the main bay of the machine shop and the boiler shop beyond will convince the observer of the wisdom displayed by the management in adopting electricity and eliminating shafting from these works. It leaves the space overhead clear for the operation of cranes, affords much better light and ventilation, and by using separate motors for each machine a more advantageous arrangement in every respect is secured. Tools may be placed wherever it is most convenient to handle the work for which they are intended, and the flexibility of the system renders it possible to transfer these tools from one part of the shop to another if necessary.

Throughout the plant Westinghouse polyphase induction motors have been adopted for operating machinery of every description and driving machine tools. Some of these include more than one motor. Many of the larger machine tools, indeed, require two or three motors, as in the case of a boiler shell drill and a large boring mill, both of which are subjects of special illustration on pages 130 to 132.

The extent and variety of operations performed by these motors and the conditions under which they work make the equipment an unusually interesting one. A few words about the general design of this type of motor and the features

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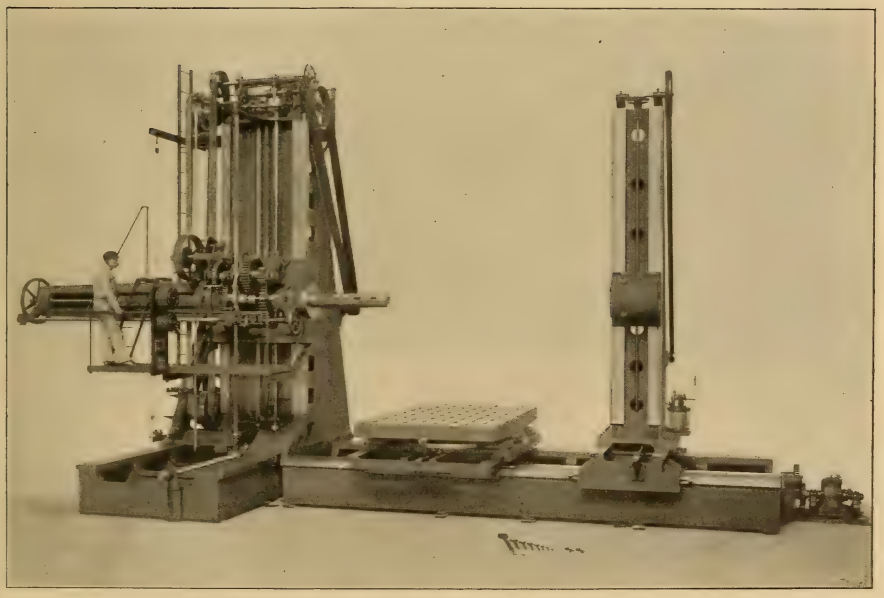
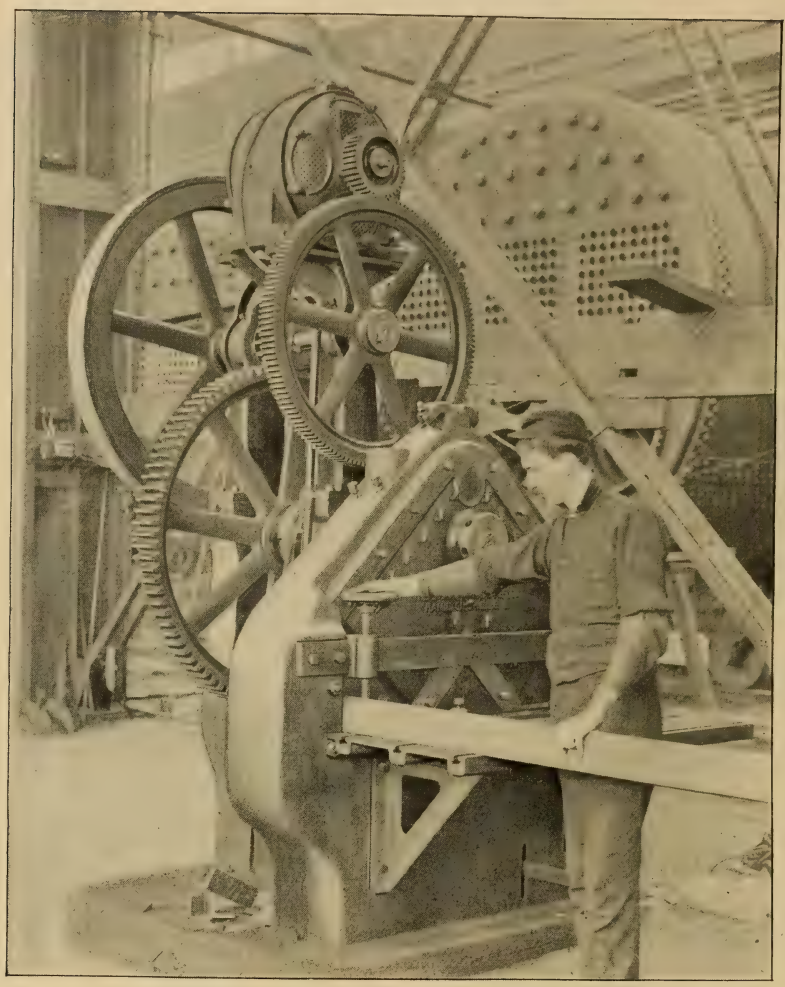
which commend it particularly for this work may be fittingly introduced here. The motor has two main elements,—the primary, which is directly magnetised by the current supplied from the power circuit, and the secondary, in which low-potential currents are induced by the action of the primary. Rotation is produced by the action between the secondary currents and the rotating field of the primary. The mechanical features of the motor are exceedingly simple, and its electrical elements are likewise free from complications. The stationary part is permanently connected to the main circuits, while the rotating part has no electrical connection whatever with any external circuit, and has no electrical contacts or adjustments. There is no sliding or working friction except that of the shaft in the journals; and the only parts that can wear, therefore, are the shaft and journal boxes. The friction in these is very light, owing to the light weight of the rotating part and the ample bearing surfaces provided. Self-oiling bearings afford liberal lubrication.

The motors may be suspended at any angle, and they may be put in out-of-the-way, almost inaccessible, places; in fact, they are often purposely put out of reach of workmen who are not familiar with their construction, but who, through curiosity, might "tinker" with them, and thus damage them. End brackets, which are parts of these motors, may be bolted to the frame in eight different positions, and the oil chambers in the brackets will still be in the proper position whether the frame is bolted to the floor, the wall, the ceiling, or at an angle of forty-five degrees. The only attention and care required by these motors consist chiefly in an occasional renewal of oil; they are thus especially desirable for continuous service over long periods of time without expert attendance.

Motors of this type, in the sizes used in this plant, may be started by connecting them directly to the circuit with an ordinary switch, but the larger motors are generally started on reduced voltages by a special double-throw switch, the full electromotive force not being applied until the motors have attained their normal speed. The starting de-



A BORING, MILLING, AND DRILLING MACHINE

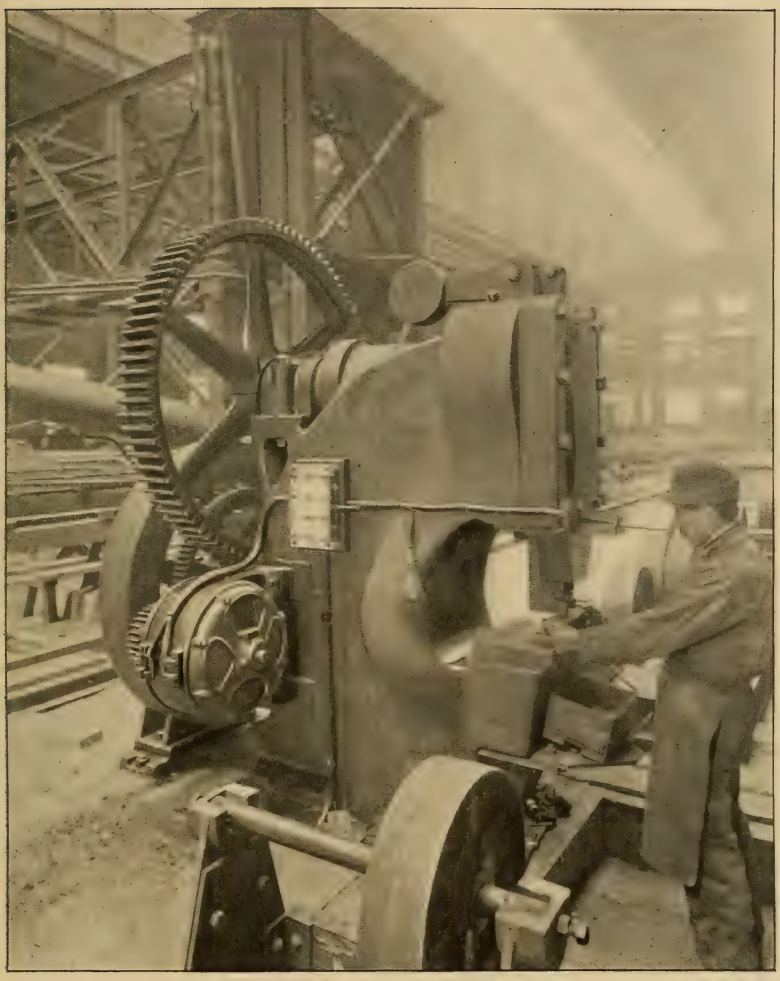


AN ANGLE SHEAR BUILT BY THE LONG & ALLSTATTER CO., HAMILTON, OHIO

vice may be remote from the motor, and this is often the case in places where there are inflammable gases, as well as when the motors are suspended from ceilings or installed in places not easily accessible, as in the installation under consideration.

It would be impossible within the limits of this article to describe in detail all of the applications in which these motors are employed, but a few of the more important and interesting combinations are illustrated, and they will serve as examples of their respective classes. The plate room contains several interesting applications. At one side is a flanging machine. The deck and bulkhead plates are taken from the laying-off tables to the joggling rolls, which bend the edges, so that wherever lapped they present plane surfaces. There is also in use in this part of the works a scarfing machine to plane off the plates to a feather edge. Beyond these are punches, shears, drills, and other tools. There are rotary shears and a 60-inch guillotine shear, on which a 50-horse-power motor has been installed to replace the steam engine with which it was originally equipped.

Two 30-foot planers are used for planing the calking edges of plates. Sev-

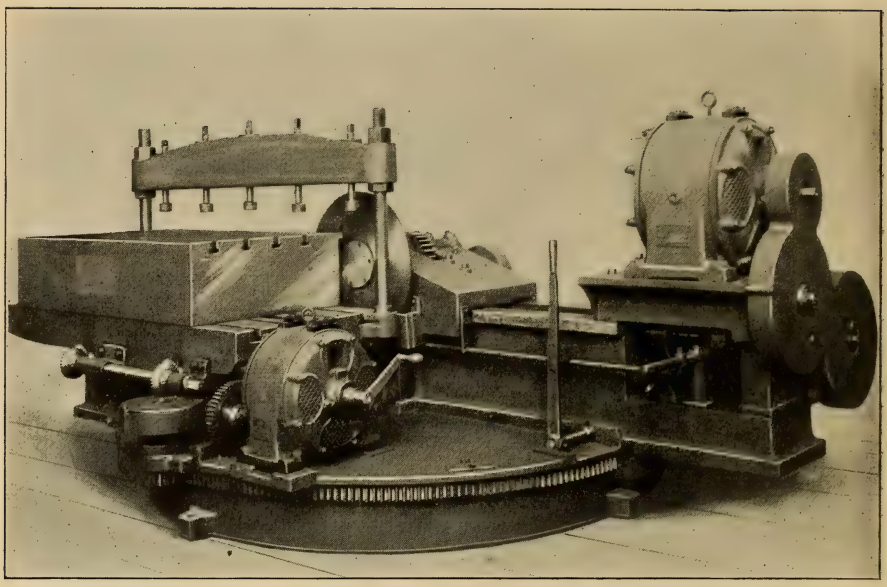


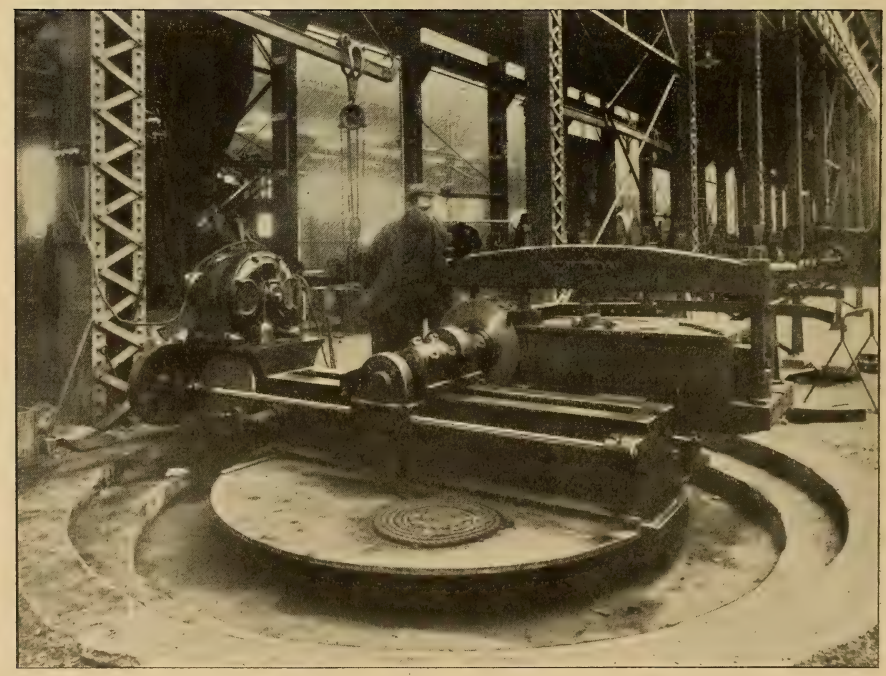
ONE OF THE MOTOR-DRIVEN PUNCHES

eral small punches for brackets and intercostals are operated at the lower end of the shop; also a horizontal punch, and a combined punch and shears which can be used for cutting limber holes. There is also a notching machine and two 6-inch radial drills. At the lower end of the shed are two rolls, one of which can handle a plate 27 feet wide; the other is used for rolling mast plates.

In the angle shop, as in the plate room, the tools used are of the latest design for handling every class of work. Among them are channel and I-beam shears; two cold saws, one mounted on a turn-table for cutting at any angle; punches for punching straight beams; a portable punch and countersinking press and angle shears mounted on a turn-table.

The main floor of the machine shop contains probably the largest and most complete equipment of tools of all sizes for this class of work to be found in any shipbuilding plant in the world. There are so many large machines on this floor that they lose the distinction they would have in smaller plants. Among the most notable are a 16-foot vertical boring mill fitted with three boring arms, two for use when the work is revolving and one when it is station-





A COMBINATION COLD SAW BUILT BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA

ary; and a large drilling, boring, and milling machine with 8-inch spindle, equipped with steel scales and verniers for placing the work on the table and measuring it in each direction. There are two band-saws for cutting steel, such as eccentric straps, built by Messrs. Noble & Lund, Ltd., a British firm, of Newcastle. There are further a 72-inch open-side planer that will take a piece 28 feet wide; a 96-inch planer which will take work 36 feet wide; two double-headed lathes, one 48 inches and the other 63 inches, each 60 feet long, and a large array of other tools, each driven by its own motor.

There is a very complete electrical repair shop in the east gallery, equipped with lathes, planers, drill presses and small tools, such as are generally found in repair shops, all electrically driven. Another shop in the west gallery is thoroughly equipped with pipe-cutting and threading machines, lathes, drill presses, and grinding machines, all likewise driven by motors.

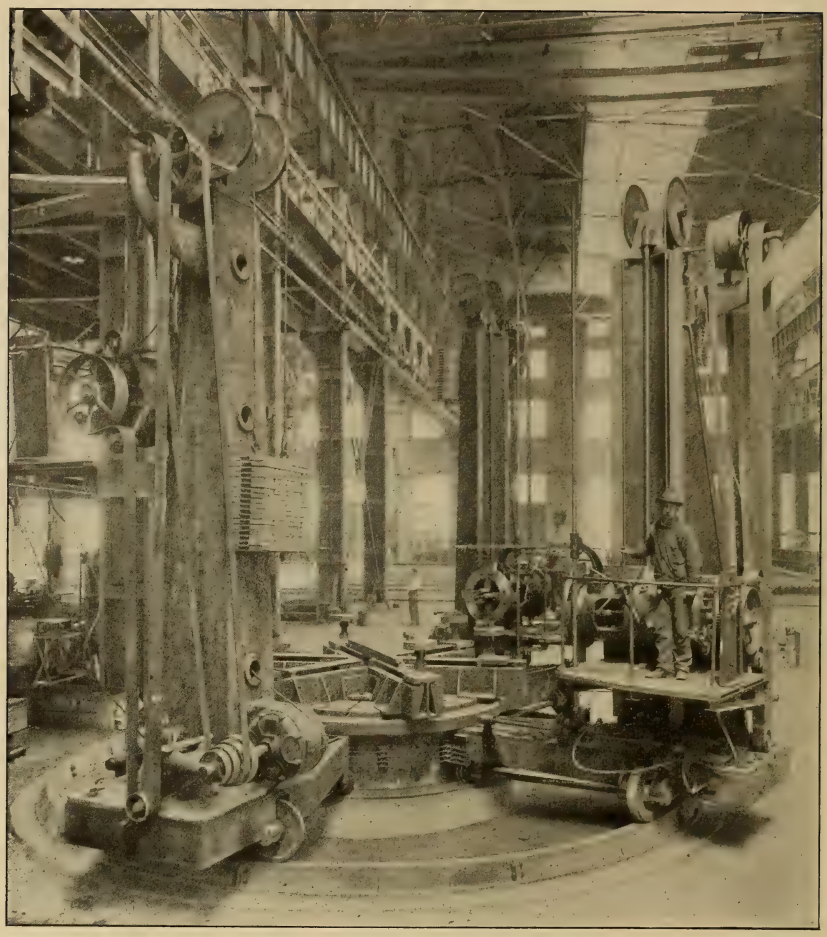
The boiler shop naturally contains many heavy tools. The plates are first rolled in the straightening machines which are all operated by electric motors, and are then put through the several processes for which they have to be heated. The shell plates are put through a vertical ten-foot roll, capable of handling plates 1½ inches thick. There is a 28-foot planing machine, and an elliptical and circular boring machine. The plates are finally mounted on a multiple vertical boiler shell drill, designed by Mr. Henry G. Morse and built in these shops. Among other tools in this shop are four 6-foot radial drills, two shears for trimming 1½-inch plates, bending rolls, horizontal punches, and countersinking machines.

The joiner shop, a two-story structure, located on the water front, is a model plant in every respect. It is equipped throughout with saws of various kinds, mortising and drilling machines, matching machines and planers. Each machine is independently driven, except some of the smaller tools, which are driven in groups. On the second story are benches for the lighter class of work. At one end of the floor is a separate room for grinding the saws and knives used in this shop.

In selecting subjects for illustration among the machines installed in this plant the attempt was made to present types that would offer valuable suggestions to shop managers, as well as novel equipments designed to meet special conditions. These applications cover a wide field of operations, and may be studied with profit by managers of works of this class.

Plate-bending, straightening, and flanging rolls form an important part of the equipment of every shipbuilding plant, and in this installation an excellent opportunity for utilising electric motors directly connected, geared and belted to this class of tools was presented. One of the most conspicuous features of the boiler shop is an equipment comprising large, vertical plate-bending rolls, driven by two motors of 50 horse-power each. These rolls were built by Messrs. Bement, Miles & Co., of Philadelphia, and are capable of handling the largest boiler plates used in these shops.

The Hilles & Jones Company, of Wilmington, Del., furnished six horizontal roll equipments of various sizes, all motor-driven. One set of six 14-inch diameter plate-straightening rolls, 10 feet 2 inches between the housings, was designed for steam driving, but a motor was attached by the New York Shipbuilding Company, and the change has proved beneficial. Another set of the same general design is furnished with six 10-inch diameter rolls, 7 feet 2 inches between the housings. One set of plate-bending and flanging rolls, 27 feet 2 inches between the housings, with a top roll 27 inches in diameter, and the lower rolls each 20 inches in diameter, has a capacity equal to bending 1⅛-inch plates the full width, or flange ½-inch plates 20 feet wide. A 50-horse-power motor drives the lower rolls, which are geared by means of cast-steel pinions. The top roll is raised and lowered by a smaller motor placed underneath the lower rolls. Another set of plate-bending rolls, 7 feet 2 inches between hous-



MULTIPLE SPINDLE BOILER SHELL DRILLING MACHINE, BUILT BY THE NEW YORK SHIPBUILDING COMPANY FOR ITS OWN USE

ings, with top roll 8 inches in diameter and bottom rolls 6½ inches in diameter, is used for light work.

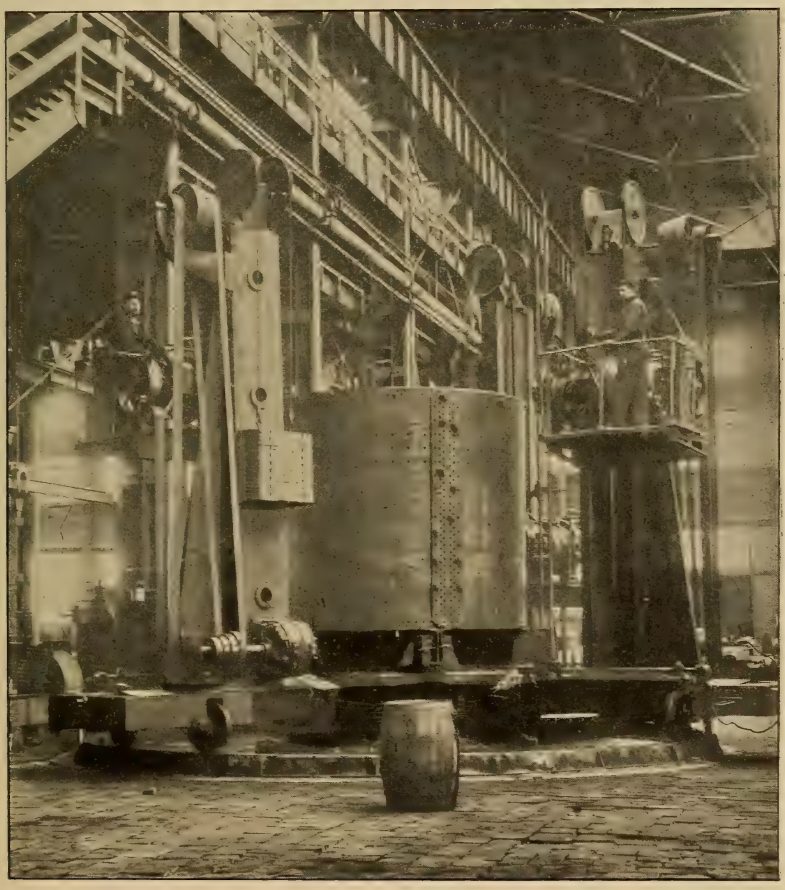
Several heavy plate planers are in service. These will plane plates 30 feet long at one setting, and any greater length by shifting the plate. Each machine is driven by a 20-horse-power motor attached at the end of the clamping beam. The motor is belted directly to the driving pulley on the machine, and special friction clutches are provided for reversing. A valuable feature of this equipment is that the machine may be reversed by the operator, or it may be set to reverse automatically at any point desired. The slide rest carries a turn-over tool-holder for planing in both directions with the same tool. The tool-holder is also arranged to swivel for planing bevels, and has a vertical adjustment for planing high angles. The machine is provided with a series of pneumatic clamping jacks which may be operated all together, independently, or in groups, as desired.

In an installation of this kind, as might be expected, a large number and variety of punches are used. Several of these are operated by electric motors with satisfactory results. The Hilles & Jones Company have furnished one vertical and three horizontal punches, all electrically operated.

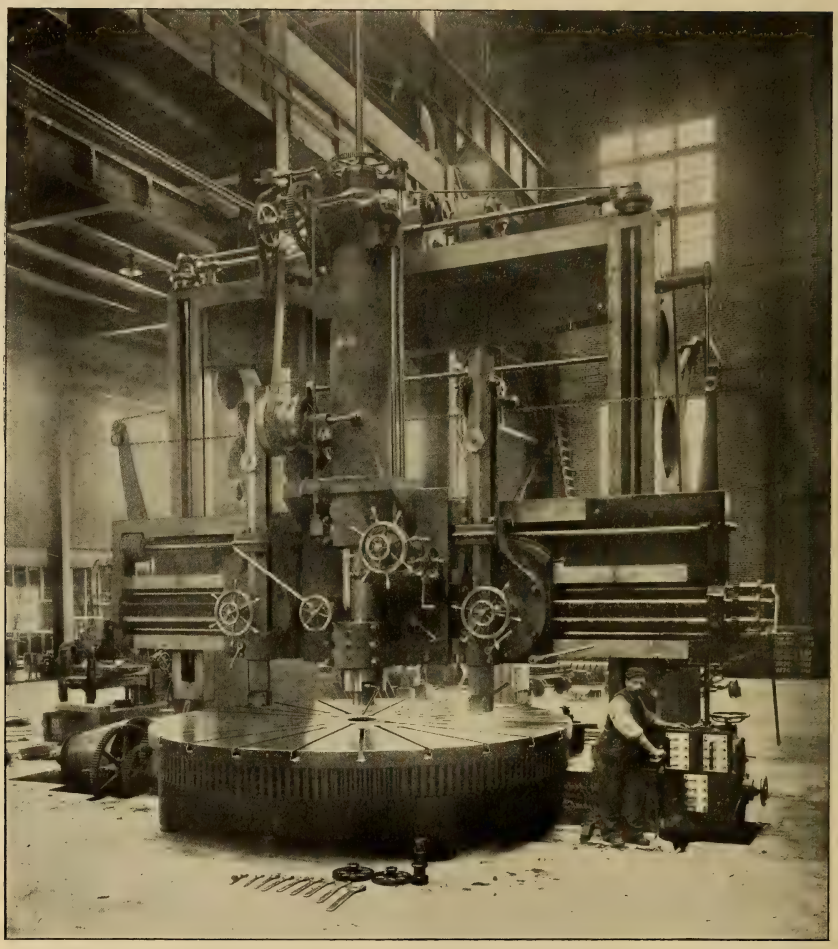
Of the horizontal punches two are of the type in which the punch stock is controlled by a hand gag, and the sliding head is running at all times when the motor is in operation. The throat depth is 11½ inches, and the tool has a capacity equal to punching 1¼-inch holes through material 1⅛ inches in thickness.

The other horizontal punch has a 11½-inch throat, and a capacity equal to punching a 1 1-16-inch hole in a 1-inch plate. Driving this punch is a motor with its pinion keyed directly to the eccentric shaft. The same company also furnished a rapid-action punch, with 30-inch throat, arranged for belt-driving directly on the fly-wheel. These machines are operated at a speed of sixty strokes per minute. They are provided with an automatic clutch for starting and stopping the sliding head, and this clutch is operated by a foot lever, bringing the punch under perfect control, in spite of the high speed at which it is operated.

Another interesting application of electric power is found in a 100-ton punch which was built by the New York Shipbuilding Company. It is driven by a 5-horse-power motor. This machine illustrates the possibilities of electric motors operating heavy tools when properly designed, and belongs to a class of apparatus formerly considered entirely



ANOTHER VIEW OF THE MACHINE OPPOSITE, SHOWING A BOILER SHELL IN POSITION FOR DRILLING



A 16-FOOT BORING MILL BUILT BY THE NILES TOOL WORKS CO., HAMILTON, OHIO

out of the electrical field; but by utilising the momentum of the fly-wheel in this combination a comparatively small motor does the work in a most satisfactory manner.

In the line of shearing and notching machines, an excellent example of motor-driving is illustrated on page 126. These machines are designed to shear right and left-hand angles, to cut them off square, or at any angle up to forty-five degrees. When mounted on turn-tables, as in the present case, these machines can be turned around from side to side and made to face in any direction to avoid handling and turning the bars. The machine shown will shear 6 by 6 by 1 inch, right or left-hand angles; it is double-geared, mounted on a turn-table, driven by an electric motor, and is also provided with a friction clutch so that the motor can be run up to full speed before starting the machine.

Universal shears or plate-splitting and cross-cutting shears, with capacity to cut 1-inch plate, are used for cutting plates, angles and bars. The lower blade is adjustable to and from the upper blade, so as to make the proper allowance for different thicknesses of material to be cut.

An interesting combination is found in the machines for cutting notches, 4 inches by 6½ inches, in channels.

These tools are turreted, so that they can be revolved, and a notch can thus be cut at any angle, without changing the position of the work. These shearing and notching machines were built by the Long & Allstatter Company, of Hamilton, Ohio, who also furnished a smaller angle-iron shear equipment, and is now completing a large motor-driven punching machine.

Probably the most interesting machine in the boiler shop is the four-spindle boiler-shell drill previously referred to and shown on pages 130 and 131. This machine has three columns, each of which has a saddle with four drill spindles arranged so that three drills on each saddle can be placed in either a horizontal or vertical plane. This machine will handle boilers up to 20 feet diameter, and 20 feet length. The details of the machine and the application are shown in the illustrations, one view representing a boiler secured in place. About it are three drill heads, each containing four spindles, which can be operated at the same time. They are adjustable in all directions. Twelve holes can thus be drilled radially at the same time, and then the drill heads can be shifted to drill twelve more holes about the periphery. Three 10-horse-power motors are employed on this machine.

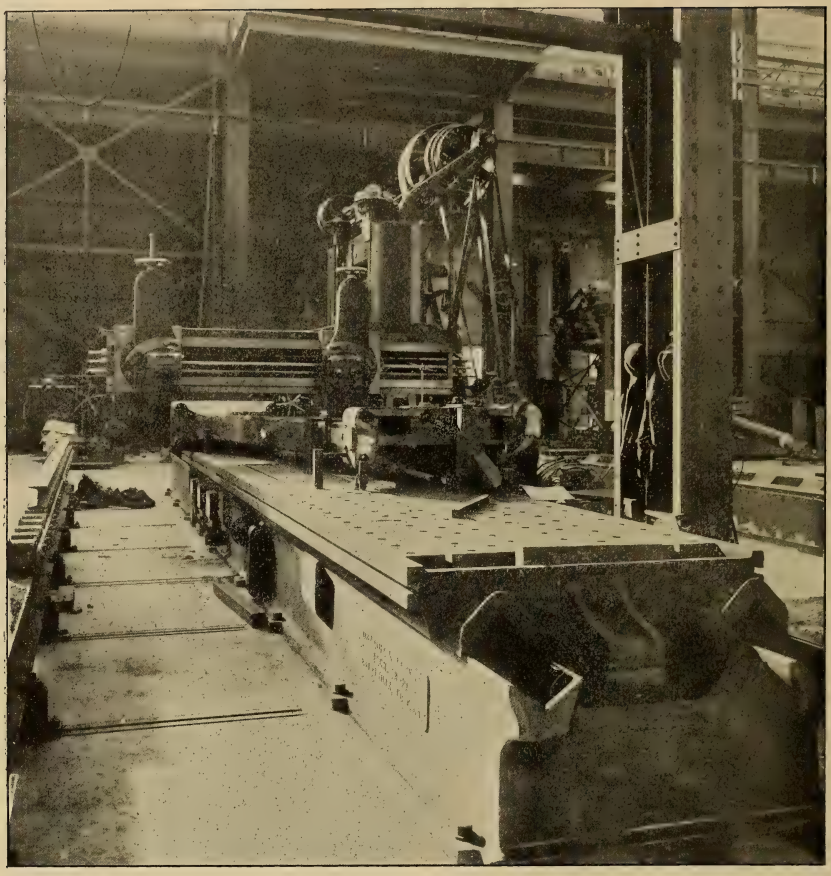
The largest lathes in the shop are two of the double-head type, made by Messrs. Bement, Miles & Co., one 48 inches by 60 feet, and the other 63 inches by 60 feet. They are capable of handling the largest pieces of work in these shops. Several motors are used on each of these tools, one having a 7½ horse-power and a 10 horse-power, and the other requiring one 5 horse-power, one 10 horse-power, and one 20 horse-power. The motors are mounted on adjustable brackets attached to headstocks and belted to cones on the machines for obtaining speed variations. Power traverse by motor is provided for the carriages on the lathes.

Two types of cold-saw cutting-off machines are employed—one for cutting bars and the other especially adapted for I-beams. The combination cold-saw shown on page 128 is an interesting application. It comprises a saw 26 inches in diameter, and has a capacity on top of the table 7 inches by 24 inches, and for I-beams on a square or mitre cut on the bottom table, 15 inches. The machine is driven by a direct-coupled 7½-horse-power motor, and is revolved on the round bed by means of a small motor. The bar cold-saw cutting-off machine employs a 24-inch saw, and has a capacity for 7-inch round bars and 6-inch square bars. A 7½-horse-power motor furnishes power for driving this machine.

Among the larger tools that attract special attention is a 72-inch open-side planer made by the Detrick & Harvey Machine Company, of Baltimore, Md. It is the largest tool of this pattern that has ever been made. It is designed to plane a surface 72 inches wide, 72 inches high, and 28 feet long, and it will take under the beam a piece of work slightly larger than the vertical dimensions given. The supplemental rolling table with which this machine is equipped is a very valuable attachment when large pieces are handled. It is shown at the side in the illustration on page 134. When in use, this table moves simultaneously with the planer platen, and requires very little additional power. It forms the outer support for wide and heavy work, and for long pieces when planing off the ends.

A 96-inch planing machine, 36 feet long, weighing 174,000 pounds, belt-driven from an electric motor, was built by the Betts Machine Company from special plans of the New York Shipbuilding Company for this plant. A 30-horse-power motor furnishes power for this tool.

The boring mill shown on page 132 swings 16 feet in diameter, and takes 90 inches under the tools, permitting the bar to travel 48 inches. The tool is fitted with three boring arms, two for use when the work is revolving, and one for use when the work is stationary. The rim of the table runs in a groove cut in the bed and flooded with oil. The table spindle is very long and has a taper bush at the top for taking up wear; the



A HEAVY OPEN-SIDE PLANER BUILT BY THE DETRICK & HARVEY MACHINE CO., BALTIMORE, MD.

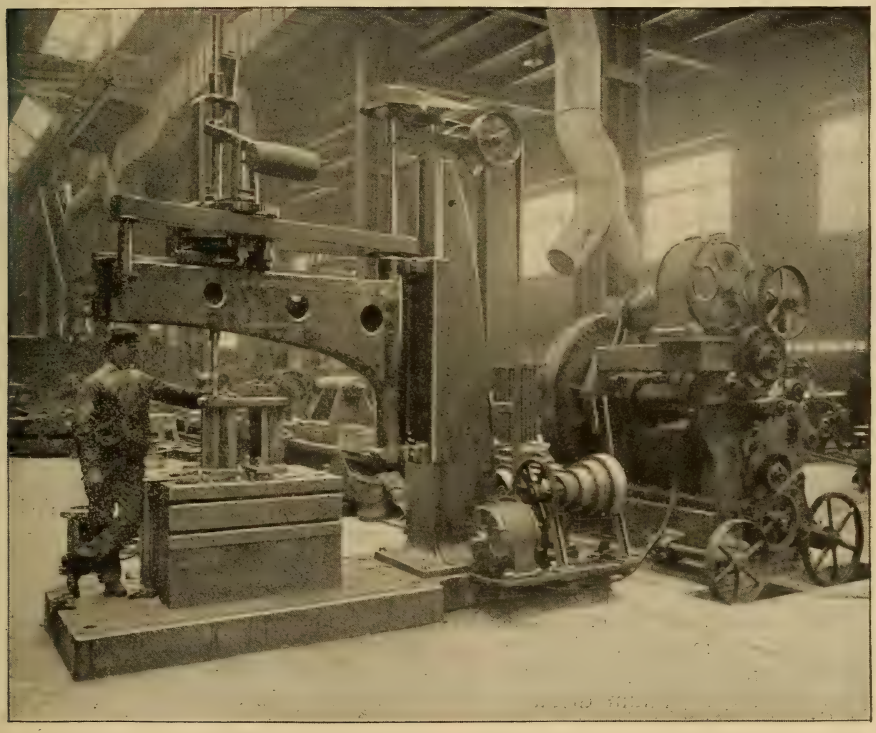
lower step runs in oil, and is supported by a heavy conical casting extending down from the bed. There is a wedge with screw adjustment for raising the table slightly off the annular bearing when at high speed. The driving cone is large and strongly back-geared, giving ample power. It is placed at the left side, within easy reach of the operator. The feeds are driven by a large, high-speed friction disk, which allows instant adjustment throughout its range while running. The gearing at the end of the rail gives an additional range of feed and allows the independent reversal of all the feeds by sliding the slip gears on the rods and screws. Three motors are employed in operating this machine. They are of 3, 5, and 10-horse-power capacity, respectively.

The Niles Tool Works Company, who built this machine, also furnished several smaller tools of the same general class, including a 51-inch and an 8-foot boring and turning mill. Another equipment furnished by the same company is a heavy 18-inch shaping machine.

The 6-foot radial drill shown on page 135 is belt-driven, a 3-horse-power motor being placed at the base of the machine. The traverse of the saddle on the swinging arm, and of the spindle, which is counterbalanced, is by means of rack and pinion so placed that workmen can operate both and swing the arm at the same time to bring the drill to the work. The belt is applied to a pulley locked to the spindle. The back gears are arranged the same as on a lathe and

are as readily thrown in or out. Thus, for ordinary drilling, the smooth motion given by a belt is obtained, and for heavy drilling the power obtained by the use of back gears is applied directly to the spindle, in place of being transmitted through shafts and several pairs of bevel gears. The machine was built by the Pond Machine Tool Works, of Plainfield, N. J.

Two drills of the horizontal type, capable of drilling at any angle, boring, and milling, and provided with universal tables, were furnished by the Detrick & Harvey Machine Company, for handling general machine work. These machines are capable of performing nine distinct operations with one chucking, and are said to be as efficient and satisfactory in each of these as separate tools would be. Each machine consists of a bed-plate, on the main portion of which is fitted a column with a traverse of 40 inches or more if desired. It may be arranged for drilling and boring only, the column having a hand and quick power movement, but automatic feeds may be attached for milling when required. To the other portion of the bed-plate is fitted the universal table, which is very strong and capable of handling work of several tons. This table has a sliding movement of 30 inches to and from the column, being operated by a rack and pinion. The top, which is 48 inches by 36 inches, has a pivoted movement from a horizontal to a vertical plane, and can be rigidly clamped at any angle. It also has a rotary movement, which makes it possible to drill holes in any part of a hemisphere or in five sides of a cube without re-chucking the work. When extra large work is being machined the table can be lifted off the bed-plate. When used for boring, an outside sup-



A RADIAL DRILL BUILT BY THE POND MACHINE TOOL CO., PLAINFIELD, N. J.

port for the bar is furnished, which can be used either with or without the universal table. Power is furnished by a motor at the base of the machine, one tool requiring 5 horse-power and the other 3 horse-power.

The boring, drilling and milling machine shown on page 125 has a spindle 8 inches in diameter. The boring head carrying this spindle has a vertical travel upon the upright of 10 feet, and the main upright has a horizontal travel along its bed of 22 feet. All movements are made by power controlled by the operator when standing on the platform attached to the boring head. The platform travels with the boring head, so that the operator is in the same relative position to the boring head at all times. The machine is driven by a 10-horse-power motor, with a special service switch to vary the speed. A heavy outboard support is also provided, the bearing of which has a vertical adjustment corresponding to the vertical adjustment of the main spindle. The adjustment of the bearing is made by a 2-horse-power motor. There is an adjustable work-table upon the cross bed which carries the outboard support. This is operated by a 3½-horse-power motor.

Another tool worth noting is a special duplex milling machine, built by the Newton Machine Tool Works, of Philadelphia, driven by a 10-horse-power motor. This machine is provided with two heads, carrying spindles 5 inches in diameter. The maximum distance between the ends of the spindles is 42 inches, and the minimum distance 9½ inches.

In addition to the separate motor-driven machine equipments mentioned, electric motors are used throughout the works for many other purposes, such, for instance, as operating the heating, ventilating, and blowing systems. In the power house a 5-horse-power motor is connected with a Green economiser, and a 40-horse-power motor drives the exciter for the generators. Two and five-horse-power motors operate ventilators. The shavings exhaust system in the joiner shop is operated by two motors, one of 30 horse-power and one of 50 horse-power, and one 20 and one 30-horse-power equipment are installed for the blower system. Shafting in the machine shop and the joiner shop is driven by motors of 5, 7½, 10, 15, and 20 horse-power capacity.

The ultimate point to which all these operations are directed is the completed ship, and this, like everything else about the plant, remains under cover until it is entirely finished, furnished, tested and ready to start into service. The assembling of parts and installation of machinery are completed on the ways and outfitting slips, and this department of the plant is the destination of every bolt and nut, every bar and plate that comes into the shop to be handled, formed or finished by the machinery and appliances already described.

The launching ways are at the end of the plate and frame shops, and are directly opposite the machine shop. The height of this portion of the building above the water is 125 feet, and the depth of the water in the slip is 30 feet at low tide. Eight launching ways have been constructed and each will accommodate a ship 650 feet long. A 100-ton crane travels over all the launching ways and the outfitting slip. It can pick up a completed engine or a boiler weighing 100 tons and deliver it on board a ship on any of the ways or in the slip. The lighter engines will be transferred bodily; those weighing more than 100 tons will be partly dismantled for removal to the ship. Two cranes of ten tons each and one crane of five tons travel over each of the launching ways and the outfitting slip.

Taking everything into consideration, the plant may be considered a model installation.

CHEMISTRY IN ENGINEERING

By William McMurtrie, E. M., Ph. D.

THE service rendered by chemistry in every department of human activity has long been acknowledged and its relations to engineering have become so intimate that the representatives of each must go hand-in-hand in much, if not all, of the work of both. Indeed, the difference between the functions of the two are comparatively narrow, for, as it is hard to find the dividing line between chemistry and physics, so the boundary separating chemistry as applied to human needs and engineering as practised in the present age must be more or less obscured. For the function of the chemist thus considered is the application of chemical laws; the function of the engineer similarly considered is the application of physical laws. Yet the chemist would be at loss without the aid of physical laws, even as the engineer would be sadly crippled in many ways without the very efficient aid of chemical laws.

In many cases they must be represented in the same person. The moving spirit of many a great enterprise must be at the same time chemist and engineer, for while it is the function of the chemist to determine the work to be done and the end to be accomplished, the function of the engineer is to devise the physical means whereby the end sought may be attained with the greatest economy. Many of the great industries are, after all, only the methods and processes of the research laboratory grown large. While in the latter the work is prosecuted with small quantities of material, in small containers, and with small apparatus, the same principles are applied in the great chemical works in the treatment of very large quantities of material in enormous containers and with apparatus and machinery involving the use of great power.

If it be considered the function of the engineer to devise and erect the great structures and generate and apply the power needed to carry out the necessary operations, all this must be done in accordance with the requirements of the chemist and in many cases under his direction. The analytical and research laboratories apply the laws of chemistry in a small way, while the great industries apply the same laws in a large way, and in modern practice the same attention to detail must be given and the same degree of accuracy must be attained.

In a very large measure the differences between the two may fitly be expressed by the terms "micro-chemistry" and "macro-chemistry," respectively. In the first, the operations are carried on without regard to the expense involved in the attainment of the end sought, while in the second, as in all engineering works, this becomes all-important. And whether this is to be attained by the chemist alone or by the engineer alone the functions of each must be exercised, the skill of both be invoked. And so in these latter days, in the institutions

of higher education, in the great professional schools and the universities special courses of study have been arranged to meet the requirements here indicated, and leading to the degree of chemical engineer.

But all this applies particularly to the operation of the great industries, chemical and metallurgical, so rapidly developing to such enormous dimensions in all civilised countries. Analytical and research laboratories have become absolutely indispensable to the maintenance of the highest economy in operation and the utilisation of products otherwise waste. The management of such laboratories must be delegated to chemists of the most thorough education and training, and it is by the application of their studies that in many of the great industries waste and worthless substances have been made the sources of great profit.

The application of the combined functions of the chemist and engineer is illustrated in very many industries. Attention need simply be called to the manufacture of acids and alkalies, the great soap works, sugar refineries, distilleries, starch and glucose works, operating daily upon millions of pounds of material in the raw state, when only a few years ago a few thousand pounds were considered large quantities to be treated. It is not long since the utilisation of 400 to 500 tons of roots was considered to be the maximum economical limit of the beet sugar factory; now 3000 to 4000 tons are handled with readiness in a single factory; 2000 to 3000 bushels of corn consumed in a starch or glucose factory were once considered a fairly large daily capacity, and now these figures must be multiplied by more than ten; a few hundred pounds operated upon in a single charge constituted the old-fashioned soap boiling; now hundreds of thousands of pounds constitute the single charge in some of the most modern works. The soda industry has grown to such dimensions that the quantities handled to-day would seem fabulous to the operators of a quarter of a century ago, while the auxiliary industries, which must be carried along with it to furnish supplies necessary to it,—lime, carbonic acid, ammonia, and others,—would have been dignified by designations of individual industries a few years ago.

What is true of the quantity of materials to be handled and treated is likewise true of the purity of the resulting products. Acids must be of the highest purity, free from everything which may in any way interfere with the substances to the production of which they may be accessory, and impurities must be reduced to parts per million. Chemicals, such as copper sulphate, potassium bitartrate, the cyanides, and other crystallised compounds, are turned out from the works in batches of several tons each, with a purity not excelled by the synthetic preparations of the research and synthetic laboratories. To handle the large quantities of material required, the engineer must provide the means, and for control of the operations to secure the high degree of purity required by modern demands, the functions of the chemist must be invoked. And what is true of the particular industries here named applies likewise to many others.

But, after all, we want to consider here the relation of the chemist to the specific function of the engineer. Considered broadly, it covers the production, control, and direction of force, the facilitation of motion, the utilisation of power. It embraces the means whereby these great ends are to be attained. It embraces the production of energy, the conservation of energy, and the direction of energy. And these three cover the work of the engineer immediately or remotely in whatever position he may find himself. It is to the relations of the chemist to these functions of the engineer that the present discussion shall be mainly devoted.

For the engineer, the production of energy includes the utilisation of natural forces and the application of heat variously generated. The most important natural force available is gravity and its most familiar exponent is the waterfall, and it is the duty of the engineer to conserve and direct the energy potential

in it. We shall not attempt to discuss the relation of the chemical action in the sun to the heat which carries water to the elevations descending from which it becomes a source of power. That chemical action, at least, does not involve the intervention of human agencies; but we might very properly consider the remote influence of the sun's energy, light, and heat, stored up in fuel, vegetable, and mineral, recent and fossil, which, after all, in the world's work, is the most important source of power.

In the space at command we may not enter too much into detail in the development of this thought. Chemical synthesis in vegetation and chemical decomposition or analysis effected by geologic action in the earth, producing the various forms of fuel,—coal, oil, and gas,—constitute special fields of study of entrancing interest. But it is in the study of the products of this synthesis and analysis that the work of the chemist not only assists and supplements, but in many particulars prepares the way for the work of the engineer. What are the constituents of these products which are of importance to the engineer, and how many units of heat will each constituent develop when combining with oxygen in combustion? What are the impurities present in the crude products which may, in one way or another, interfere with their perfect work? It remains for the chemist to answer all these questions in the analytical and research laboratories, and the balance and the calorimeter are his most valuable aids.

Furthermore, after the chemist has determined the composition and value of these crude natural fuels he must also determine how they must be prepared for ultimate utilisation. The forms of coal may, in many, if not in most cases, be used directly after the mechanical preparation carried on at the mine; but it frequently happens that these forms are not suited to prevailing exigencies, and destructive distillation in coking establishments and in the gas works, and fractional distillation of oil in the refineries become the means necessary to the end in view. Fuel which is too soft for the great load put upon it in the enormous metallurgical furnaces of this era must be subject to destructive distillation in the coke oven, producing coke on the one hand and gas on the other, which may, respectively, be applied as needed. And modern practice and modern necessities require the greatest economy, which, in turn, involves the recovery and utilisation of the volatile liquid products of this destructive distillation. It is in cases like this that the chemist and engineer must work together and in harmony; the chemist to indicate the operations to be carried out, the engineer to devise means for effecting this in a large way. It is this co-operation which has been so effective in illustrating the wastefulness of the long-used beehive coke oven, and has shown the enormous economies to be secured in the substitution of the by-product recovery ovens now rapidly being introduced.

While the engineer cares for the great masonry and other construction necessary to effective operation, the means for transporting, handling, and storing the crude and finished products, the chemist controls the conditions necessary to the effective operation and the quality and utilisation of finished and by-products. The finished products,—coke and gas,—are of special interest to the engineer, while the tar and other liquid distillation products lead to industries of more particular interest to the chemist,—the manufacture of ammonia, of cyanides, antiseptics, and dyes.

All this applies equally well to the modern distillation of wood, in which charcoal, formerly the principal product, has become almost a by-product, while the gaseous and liquid distillation products, which, in the old methods, were consumed by burning or were allowed to go to waste in the air, have become, in many respects, the principal products.

The fractional distillation of crude mineral oil and the consequent separation of its constituents, the good from the bad, the pure from the impure, the useful from the more or less useless,—for in these days none is absolutely useless,—are no less important. In this

industry the enormous quantities of material treated in a single operation make such calls upon the functions of the engineer that co-operation is necessary whether it be represented in two persons or be combined in a single individual.

And when the fuels have been prepared for use in the production of heat and light their study in the chemical laboratory constitutes a control necessary to every well-ordered engineering plant, for whether the fuel shall be used in the generation of steam for power or whether the gas shall be used for the production of light or the development of power in the gas engine, its chemical composition, but more particularly that of the products of its combustion under the conditions prevailing, are of prime importance, and few, if any, power plants, well organised and of the highest efficiency, lack the aid of a competent chemist with all the appliances for effective work. He must determine whether the fuel used is of a composition to correspond with that specified, and, by repeated analysis of products of combustion, determine that everything available has been consumed in such a way as to secure all the energy obtainable. It is only by such means that the highest economy can be assured.

It is interesting to know that when one visits some of the great power plants recently erected for generating power for electric tramway service not the least important parts of them are the well-equipped chemical laboratories for the study of every question connected with the generation of power.

What has been said regarding the preparation and utilisation of fuel for the production of power so closely relates to the requirements for the production of gas for light that the latter need not be separately discussed. The modern gas-light plant, usually of enormous dimensions, is simply one huge chemical laboratory, and the ramifications of the chemist's work therein is a fit subject for separate interesting discussion.

In the conservation of energy the intervention of the chemist is little less important. Attention has already been called to the importance of the composition of gas to be used for generation of power in the gas engine; but notwithstanding the high efficiency of this agency the most important means thus far devised for the generation of power is through the production of steam, or the transfer of the energy developed in the combustion of fuel to water and its vapour. The highest economy and efficiency in this transfer of heat energy to water require that the water employed shall be free from mineral constituents, which, on the one hand, separating and becoming deposited upon heating surface, may interfere with the proper and ready transfer of heat, and, on the other hand, may injuriously affect the material of the boiler in which steam is generated. Careful chemical study of water supplies has been of enormous advantage to the engineer, showing him what to accept and what to avoid in filling his needs in this particular. And if, as unfortunately so frequently happens, no choice is left, and water charged heavily with troublesome and injurious impurities must be employed, it becomes an important and often difficult problem to devise means for removing these impurities or for neutralising their injurious effects.

So waters containing carbonates and sulphates may become destructive of economy by depositing upon heating surfaces crystalline scale which impairs the transmission of heat, and thus to a corresponding degree reduces the effective heating surface in the steam generator; or waters containing chlorides become troublesome because of their corrosive action upon the metal of the generator. Waters must, therefore, be subject to study by chemical analysis to determine the quantity and quality of the mineral constituents they contain, and subject also to experimental study to determine the means whereby the difficulties inherent in them may be ameliorated or removed.

When the solution of this problem has been effected, the means for handling, treating, and storing the large volumes of water to be treated rest with the engineer, or the chemist must in this

case be his own engineer and work out the details of construction for himself.

Conservation of energy in the steam generator has been, until recent years, the most important of all in any way of interest from a chemical standpoint. But in this age of electricity, with its new means of transfer of energy, the storage battery has come to be of enormous importance in the conservation of energy, and its very existence and functions depend solely upon chemical reaction. The comparatively simple device of its great inventor, Faure, failed to meet the hard conditions of actual use, and the commercial needs, stimulting the chemist's and mechanic's skill, have brought forth the modified and excellent forms of battery of the present day.

In the direction of energy the function of the engineer has far wider range than in either of the two divisions thus far discussed. It further engages the attention of the mechanical and electrical engineers, but it likewise covers the work of the civil and the architectural engineers. The field of operation is, therefore, extended not only to the construction and operation of machines for direction of energy,—the transmission of power,—but as well to the provision of the great structures which constitute the monumental evidence of the skill of the civil and architectural engineer. For while it is the function of the mechanical engineer to reduce resistance to energy applied to machines, it is the function of the civil engineer in many ways to provide effective resistance to the potential energy resident in large masses of material to be supported in structures erected for various uses.

Resistance in transmission may be reduced in various ways, and in all cases such reduction depends upon reduction of friction. This may be accomplished, or, at least, facilitated by different means, most important of which is the provision of bearings of proper physical condition. This depends largely upon chemical composition, and, in addition thereto, on the use of proper lubricants. It rests with the chemist to determine what combination or composition of metals is best suited to the purpose indicated and similarly what combination of oils,—vegetable, animal, and mineral,—soaps, and other substances best meet the demand. Earnest effort is constantly being devoted to the production of anti-friction metals and of lubricants, and while the aid of the chemist is needed to build up these substances, it must likewise be invoked to detect imposition of fraudulent and adulterated materials upon the inexperienced and uneducated.

The chemical study of the materials of engineering has always been important and interesting, and the importance of this study grows with the years. In structural materials we have mortars and cements, iron, steel, and other metals, and timber, the compositions of the best forms to insure greatest strength, as well as the deteriorations which these may suffer under atmospheric and other agencies, the substances which may, and do, prevent such deteriorations,—paints, oils, varnishes for metals,—the protective ingredients and coatings and all that goes with them. All these have had their share of attention, and it is particularly stimulated at the present time when so much discussion is being devoted to the longevity of the metal framework of tall buildings and long bridge spans. Such attention from the chemical side is always of benefit to the engineering side.

How important chemistry is to engineering work is well illustrated in the attention given to the matter by some of the great railway systems. The value of chemical aids to the engineer was probably first recognised by the Pennsylvania Railroad, in the United States, and the systems of study of engineering problems in the chemical laboratory developed by the distinguished chemist of that railway, Dr. C. B. Dudley, have had world-wide recognition. His work has grown to such dimensions that in his well-equipped laboratory twelve educated chemists are kept constantly busy. In a private communication Dr. Dudley says:—

"The work done in a year involves about 35,000 determinations. * * * * It is difficult to give the total money

value of the contracts represented in the testing of material, but it is safely three to four millions per year. * * * * We have twenty purely chemical specifications and eight chemical and physical specifications. A specification once prepared, is made by the purchasing agent a part of the contract on which materials are bought, and it then becomes the duty of the testing department to see that materials conform to the specification. This provides about two-thirds of the work. * * * * Also the demands of the country require progress in many matters, notably car ventilation, car heating, car lighting, disinfection, etc. A large amount of work is done in water analysis and coal analysis. Railroads are asked to carry dangerous materials, explosives, combustible materials, and the testing department must study rules and regulations whereby such materials may be safely transported.

"Not once, but a good many times, on issue of a specification, we have found that manufacturers did not very well understand their own product, and they were forced to study not only their products, but their methods, so that in reality we put a good deal of pressure toward progress in manufactures."

So Mr. C. P. Van Gundy, of the Baltimore & Ohio Railroad; Mr. S. S. Voorhees, of the New York Central & Hudson River Railroad; Mr. Max Wickhorst, of the Chicago, Burlington & Quincy, as well as the chemists of many other railways, direct work similar to that of Dr. Dudley and his corps of assistants, and follow, in a large measure, the systems he has developed.

From the annual report of the laboratory of the Chicago, Burlington & Quincy Railway Company, kindly furnished by Mr. F. M. Clark, Superintendent of Motive Power of the road, it is learned that in that laboratory there were tested during the year, among other things, and in numbers stated, samples of the following materials:—Axles, 13,259; cement, 171; copper, 34; iron, various kinds, 500; lead, 12; oil, 17; phosphor-bronze, 28; soda-ash, 2; steel, various kinds, 1863; coal, 33; glycerine, 2; glue, 2; limestone, 1; lye, 5; oils, 11; paints, 24; waters, 46.

These data illustrate, in a measure, the wide range of materials to be studied, and this list does not include studies constantly being made in preservation of wood used in structures and in the ground against fire and decay, respectively.

It would be impossible even to touch upon many of the more important applications of chemistry in engineering work, and certainly out of the question to discuss them in detail. Before leaving the subject, however, attention should be called to the work of the chemist in municipal engineering. In the great cities, and even in the small towns, the problems of street construction, care and repair, of water supply and disposal of sewage, the lighting of streets, and heating and ventilating of buildings, and many other problems all require the intervention of chemistry in their solution. The leading cities of the Old World have established well-organised and equipped municipal laboratories in which the chemical work of all the municipal departments and boards is cared for. All that the railway must do and much more must be provided in the great cities. The quality of materials of engineering used in city works must be studied and inspected, specifications provided, problems worked out, and the time cannot be far distant when the usefulness of the chemist's aid in most, if not all, lines of engineering work will be universally recognised.

THE USE OF ALCOHOL IN GERMANY

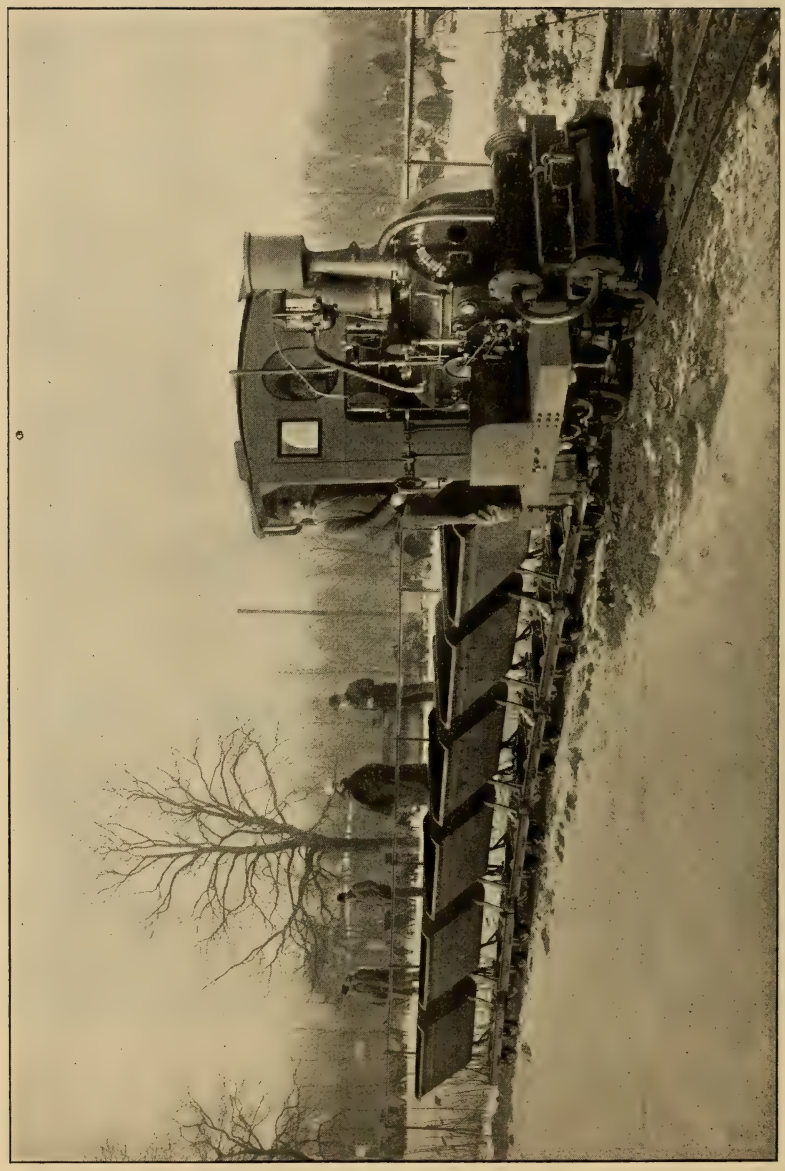
FOR HEAT, LIGHT, AND POWER

By Frank H. Mason

ALMOST interesting and suggestive special exposition, held at Berlin last February and March, was that of the German alcohol industry. It was located in a large group of buildings erected for exhibition purposes by the National Brewers' Association in a northern suburb of Berlin, and, although remote from the business portion of the city, it attracted a large attendance, mainly of persons more or less directly concerned with the production or with one or more of the many and rapidly increasing uses of alcohol for domestic and industrial purposes.

A RACING AUTOMOBILE DRIVEN BY AN ALCOHOL MOTOR

In a Consular Report submitted to the United States Government at the time by the writer, it was explained that for several controlling reasons this whole subject has reached in Germany a stage of development which gave to the recent exposition a suggestive meaning for agricultural and industral economists in other countries. Germany has no natural-gas wells or native petroleum supply. When, some years ago, the question of adopting motor carriages for military purposes was under discussion, it was remarked by the officials of the War Department that kerosene and gasoline engines could be operated only with one or other of the products of petroleum, which is not obtained in Germany, and the supply of which might, in case of war, be wholly cut off. But the broad, sandy plains of northern and central Germany,—in fact, all agricultural districts of the Empire,—produce in ordinary years cheap and abundant crops of potatoes, from which alcohol is



AN ALCOHOL LOCOMOTIVE AND CONSTRUCTION TRAIN, MADE BY THE DÜRR MOTOREN GESELLSCHAFT, BERLIN

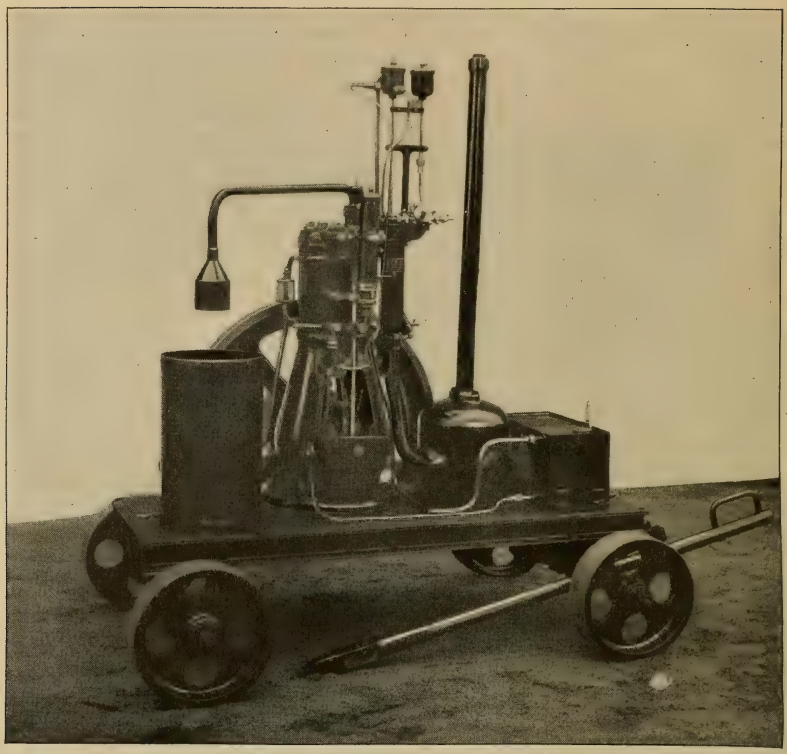
easily manufactured, by processes so simple as to be within the capacity of every farmer.

The crude molasses left as a refuse product of the raw beet-sugar manufacture contains from 40 to 50 per cent. of sugar which cannot be crystallised, and this can also be utilised as a material for the production of alcohol. Under these conditions "spiritus," as it is known in Germany, became one of the standard and important products of agriculture, and every effort has been made by the imperial and State governments to promote and extend its use for domestic and industrial purposes. Inventors and scientists have been busy with improvements in the processes and machinery of distilleries. New and highly perfected motors, lamps, and cooking and heating apparatus have been devised and put in use, until crude alcohol is becoming one of the most widely utilised products of German industry.

Official statistics show that during the year 1901 Germany consumed for technical purposes no less than 116,000,000 liters (30,624,000 gallons) of denaturised alcohol, on which no tax was paid. As a concrete result of these conditions, and the pre-eminence of the Germans in every form of applied chemistry, the recent exposition was typical, and fairly represented the highest results yet attained in the production and utilisation of alcohol. As such, it supplemented and largely amplified in scope the special exposition of spirit engines and motor carriages held at Paris last year.

A MILITARY MOTOR WAGGON. A "SPIRIT" ENGINE HERE, TOO, FURNISHES THE POWER

The exhibits were grouped according to their nature in five general classes, viz.:—1.—Apparatus for the manufacture of alcohol; 2.—Motors and motor carriages; 3.—Illumination by spirit light; 4.—Heating, cooking, etc., by alcohol flame; and 5.—The uses of alcohol in chemistry and the useful arts. They were catalogued under ninety-nine serial numbers, each of which covered the collective display of a manufacturing firm or company. Some of these comprised under a single catalogue number twenty or more different articles, as, for



A PORTABLE 2½-H. P. ALCOHOL MOTOR FOR GENERAL SERVICE

instance, a complete outfit for a scientific modern distillery, with the machinery for grinding corn, macerating, fermenting, and distilling potatoes; or for the treatment of maize and molasses waste as raw materials. This department, although interesting and important to those concerned in the industry, was, for obvious reasons, the least attractive and popular feature of the exposition.

Of far greater general interest was the department of spirit motors which were shown in all forms, upright and horizontal, stationary, portable, and locomotive, and applied to various types of motor carriages. In a lot adjoining the exposition building a circular railway of narrow gauge had been constructed, upon which trains of ten or a dozen cars were drawn by alcohol locomotives. These were adapted for service on large farms and sugar plantations, and for mining, tunneling, and engineering operations where quantities of earth, stone, or other materials were to be transported short distances. The locomotives were of the vertical-cylinder type, and carried a fly-wheel to balance the motion of the engine.

Adjoining the railway was a large, open shed in which was exhibited, by the Daimler Company, of Cannstadt, a 10-horse-power engineer's waggon, carrying tools and apparatus for a regiment of sappers and miners in field service. It was substantially built, had a speed up to ten miles an hour, and is said to have proved serviceable and efficient in actual use. Kühlstein & Co., the Berlin carriage makers, exhibited an alcohol motor waggon and a coupé and runabout propelled by spirit motors, but the display in the department of vehicles fell short in extent and variety of that in Paris last autumn, which was one of motor carriages only.

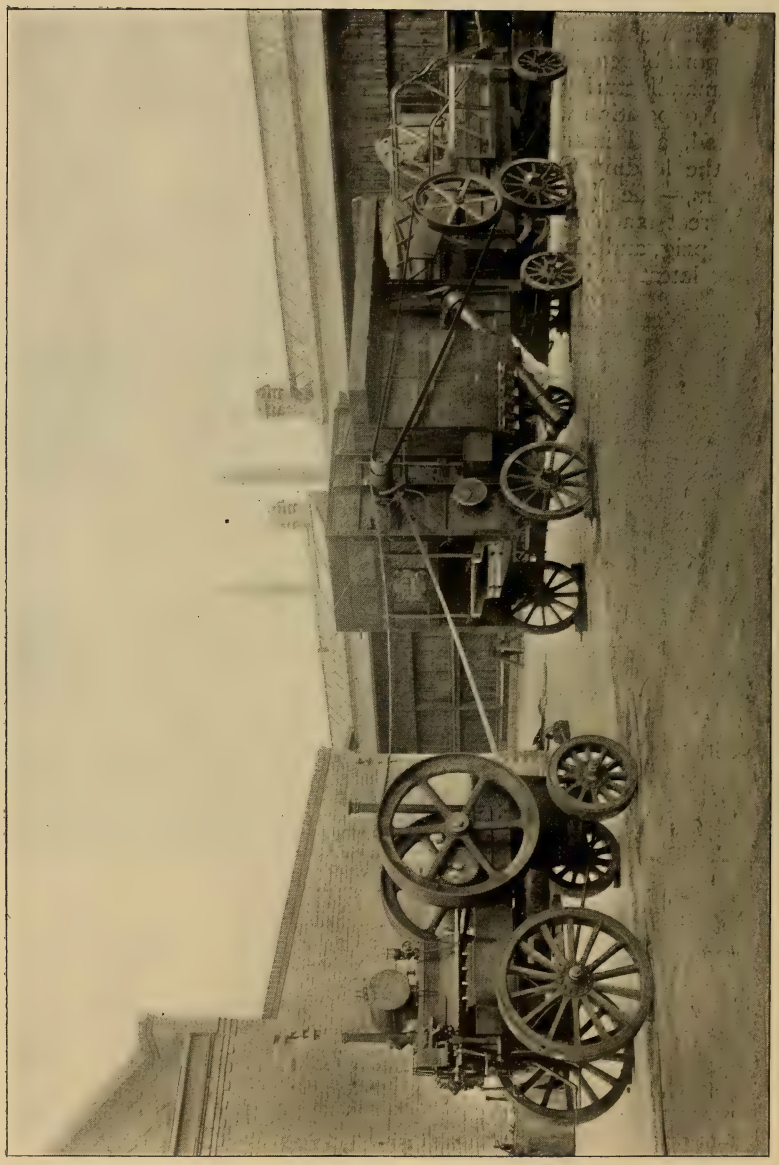
Owing to stringent police surveillance and many troublesome formalities, auto-

mobiles for pleasure and sporting purposes have found, thus far, a rather lagging and uncertain acceptance in Germany, and in this respect alcohol motor carriages have shared the general experience. But it was in the class of stationary and portable engines for agricultural and manufacturing purposes that the Berlin exposition was profuse, keenly contested, and instructive. In this class, all the leading German gas-engine builders,—the Helios, Otto, Körting, the great machine companies of Dresden, Leipzig, and Marienfelde,—exhibited their latest and most highly

A GOODS TRUCK

improved creations. These included caloric engines in all forms and sizes, from 1 to 20 horse-power, built specially for the consumption of alcohol, as distinguished from oil, benzine, gasoline, or coal-gas engines of established types. Most of them were shown in motion, geared to rotary pumps, circular and band-saws, mills for grinding corn, or turning the machinery of distilleries. The Schuckert Company, of Nuremberg, exhibited a 12-horse-power military field-lighting waggon, in which a dynamo, driven by a double-cylinder spirit engine, generated electricity for lighting a camp, headquarters, or group of hospitals. It was self-propelling, and had a speed of five to ten miles an hour.

Theoretically, alcohol has only three-fifths of the thermal value of petroleum, but it has been found that for motor purposes 28 per cent. of the theoretic energy of alcohol can be utilised against a maximum of 15 per cent. in case of petroleum and its products. This advantage in favour of alcohol is still further increased by an admixture of 16 per cent. of benzol. Another important advantage of alcohol, which applies specially to its use in motor carriages and in engines for operating creameries and small manufacturing plants in premises adjacent to dwellings, is its absolute cleanliness and freedom from the mephitic odours which make hydrocarbon engines so offensive to many people. At its present price of fifteen marks per hectoliter (about thirteen and one-half cents per gallon), it competes economically with steam and all other forms of motive energy in engines of less than 20 horse-power for thrashing, pumping, and all other kinds of farm work, so that a large percentage of the spirit produced in agricultural regions remote from coal

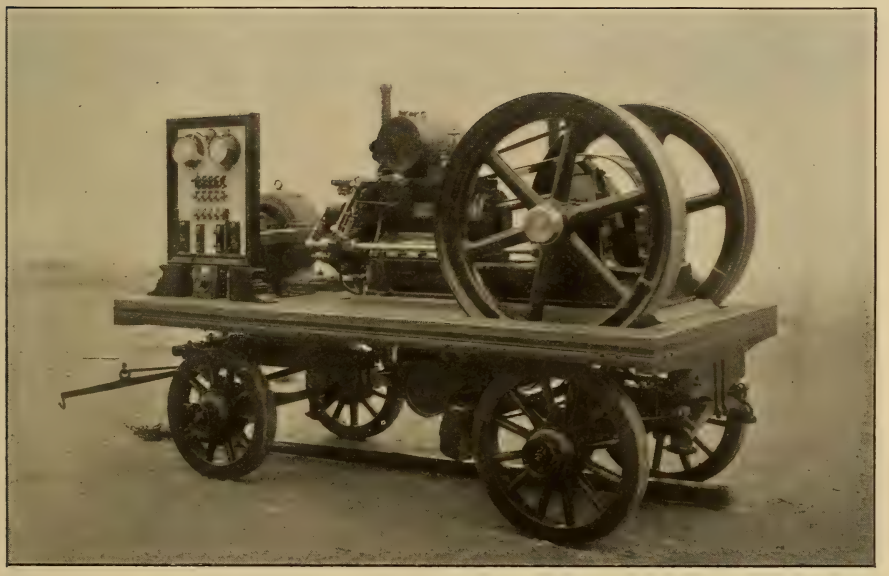


AN ALCOHOL FARM ENGINE DRIVING A THRESHER AND STRAW PRESS. MADE BY THE MOTORFAHRZEUG-UND MOTORENFABRIK, BERLIN

fields is consumed in the district where it is grown. The motor for farm use is tightly enclosed and free from danger of fire.

Next in order of importance are the uses of alcohol as fuel for cooking, heating, and a vast range of scientific and domestic purposes. Accordingly, the exhibition included a great variety of alcohol stoves for warming and cooking, and a large kitchen in operation and accessible to visitors supplied the restaurant, which is an indispensable adjunct of a German exposition. There were spirit lamps of all the most improved types for household as well as scientific processes. One of the neatest of the many new devices shown was a spirit flatiron, handsomely nickel-plated and polished, and provided with a small reservoir, which, being filled with alcohol and lighted, heated the iron for two hours' work at a cost of less than two cents. The cleanliness and economy of these fixtures, especially in summer, to housekeepers beyond the reach of a city gas supply is obvious.

Not less attractive was the department devoted to lamps and lighting apparatus. This was all the product of the past five or six years, and dated from the comparatively recent discovery that alcohol vapour, burned in a lamp hooded with a mantle of the Welsbach type, produced an incandescent light of intense power. In this special field alcohol leaves petroleum behind and approaches the illuminative power of electricity. The display in this department included a large range of portable and fixed lamps and illuminators for all locations and purposes. All were similar in theoretic construction. There was the reservoir filled with spirits from which a wick of multiple strands led to the burner, hooded with the incandescent mantle and shielded by an Argand chimney. Here, as well as in the departments of power and heating, the cleanliness and inoffensiveness of alcohol as a burning material was most noticeable. Even in the galleries of the exposition building, in which hundreds of engines, lamps, stoves, and other devices were in constant operation, there was no trace of unpleasant odour nor any heat that was oppressive or uncomfortable on a winter day.



A PORTABLE ALCOHOL ENGINE AND DYNAMO FOR ELECTRIC LIGHTING

The department of chemical preparations included, among many other spe-

A PLEASURE CARRIAGE AND AN OMNIBUS, BOTH WITH SPIRIT MOTOR SERVICE

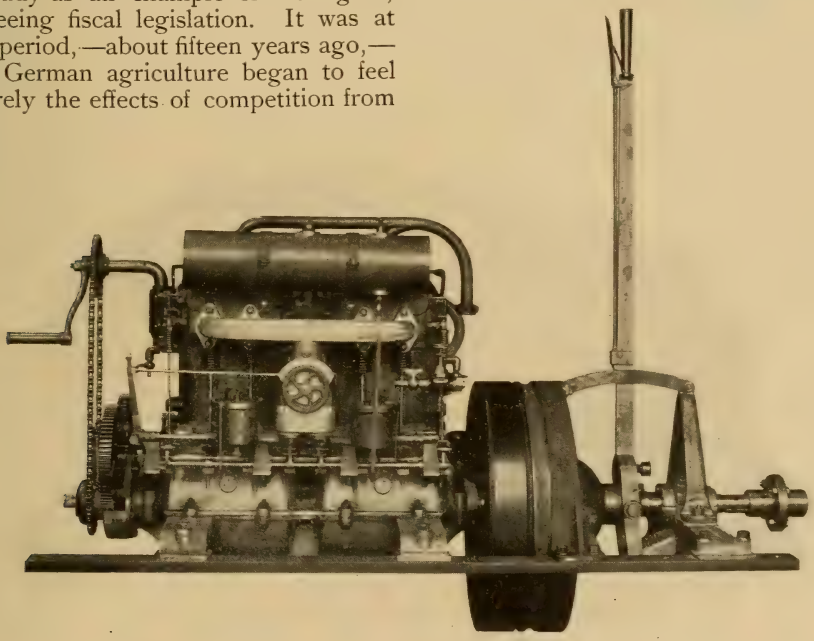
cialties, solidified alcohol,—a brown, translucent mass,—which is generally used in small cubes as a convenient form for transportation. It lights readily, can be carried in the pocket, and may be employed as a detergent for cleaning textile fabrics and most other technical uses of alcohol. There was also a large display by several leading makers of vinegar from alcohol and acetic acid. This industry is mainly the growth of the period since 1887, and its extent may be estimated from the fact that there is consumed in Germany annually for the manufacture of vinegar 16,000,000 liters (4,224,000 gallons) of alcohol.

The display of chemical products led into the aldehydes, amyl-alcohol, the

ethers, ethyls, and other technicalities beyond the scope of this article. It will suffice for the present purpose to say that in aniline and other important branches of chemical manufacture alcohol is a profuse and indispensable ingredient, and one of the potent advantages which has given Germany her supremacy in the manufacture of coal-tar colours, as well as lacs, varnishes, perfumes, and a vast range of pharmaceutical products has been the wisdom and foresight of the government in promoting a plentiful supply of cheap, untaxed alcohol for use in the industrial arts.

The German law governing the technical uses of alcohol was enacted in 1887, and, by reason of both its underlying causes and practical results, is worthy of study as an example of intelligent, far-seeing fiscal legislation. It was at that period,—about fifteen years ago,—that German agriculture began to feel severely the effects of competition from the cheaply grown cereals and meats of the United States, Argentina, and Australia. The landowning class, including the influential nobility,—which had been for centuries loyal and steadfast supporters of the Crown,—urgently demanded legislation which would save the waning profits of husbandry. Alcohol was a direct secondary product of the sugar manufacture, and could, besides, be made from potatoes, a spring crop of which could be planted as a recourse on ploughed-up fields of winter-killed wheat and rye. Moreover, alcohol was an indispensable raw material for the chemical industry, and might be made to replace, for certain purposes, the by-products of petroleum. It was accordingly decided to make alcohol for technical uses as cheap as possible, and to promote by all practicable means its production and consumption in Germany.

The law was, therefore, so framed as to maintain the high revenue tax on alcohol intended for drinking, but to exempt from taxation such as should be denaturised and used for industrial purposes. Denaturisation is accomplished by mixing with the spirit a small proportion of some foreign substance, which, while not injuring its efficiency for technical uses, renders it unfit for consumption as a beverage. The denaturising substances employed depend



AN ALCOHOL LAUNCH MOTOR

upon the use to which the alcohol is to be subsequently applied. They include pyridin, picolin, benzol, toluol, and xylol, wood vinegar, and several other similar products.

As a result of this system Germany produced and used last year 30,642,720 gallons of denaturised spirits, as compared with 10,302,630 gallons used in 1886, the last year before the enactment of the present law. Of this amount about two-thirds were of the ordinary grade for power and heating purposes, such as costs at present thirteen and one-half cents per gallon. The remaining third of the entire amount was denaturised for lighting and chemical purposes, or used pure under certain restrictions for the manufacture of perfumes, extracts, and medicinal preparations. The second or higher grade of denaturised spirit, such as is burned in lamps or used for cooking and heating, sells ordinarily for about twenty-five cents, or a shilling, a gallon, but on account of the enormous potato crop of last year, the heavy production of alcohol, and the stagnation in many industries which are consumers of spirits the price has been reduced by the national association, or syndicate, of alcohol producers to the equivalent of 21.7 cents per gallon. The wisdom of the system established by the law of 1887 has long ceased to be a question of debate. For every reichsmark of revenue sacrificed by exempting denaturised spirits from taxation the Empire and its people have profited ten fold by the stimulus which has been thereby given to agriculture and the industrial arts.

ANCIENT METALLURGY

By Henry Leffmann

SO important a feature of modern life are metallurgical operations that the history of the development of the methods seems likely to interest many. Unfortunately, however, the data for such history are scanty for all but the latest periods, and even the available material is restricted by the uncertainty of translations.

As stated by the writer in a recent presidential address before the Engineers' Club of Philadelphia, the few metals that exist usually in the free state and are widely distributed were naturally used at an early period. Gold and silver were the best known. It is an interesting example of the methods of the ancient philosopher that the discovery of mercury is not recorded. It would seem that the first obtaining of this peculiar body would have attracted great attention, and that the discoverer would be famous; yet, though the earliest mention of the metal is in a work by Theophrastus, about 300 B. C., we have no account of the place, time, or circumstances of its discovery, or the name of its discoverer.

The metals which occur regularly in the free state are mostly quite rare. Two of them, gold and silver, have such distinct physical properties as to attract special notice, and it was natural, therefore, that the earliest operations of the metallurgist should be largely concerned with them, and that their use for ornamentation and as a standard of value should be widespread. As a matter of fact, as far as we can allow a scientific character to the financial methods of ancient times, silver was rather the standard of value than gold. For many centuries a ratio between these two metals was maintained, at least by common consent, with little variation; it has been only in our own day that this ratio has been so seriously disturbed as to introduce bitter disputes into the fields of finance and politics. Evidence of the great value and importance of gold and silver abounds in the earliest literature. "The gold of that land is excellent," was said of the region watered by one of the rivers of Eden.

It is now well known to metallurgists that the native metals are rarely pure. The amount of alloy is usually such as to be subordinated to the main ingredient, but a native alloy of gold and silver, called "electrum" by the Greeks and "asem" by the Egyptians, was long mistaken for a distinct substance. A peculiar position was occupied by lead. According to the Greek alchemists, this metal was the generator of other metals. It was especially the generator of silver. We have no difficulty in understanding how this last error arose. Lead ores usually contain some silver, often very considerable amounts, and the operation of cupellation easily burns off the lead and leaves the button of silver, in which small amounts of gold are often found.

The ideas of the ancient workers were naturally largely dependent on the results of furnace operations. The strong acids were unknown. Some results were obtained by amalgamation,—that is, by the use of mercury,—but, as already noted, this element was apparently not known earlier than the time of Aristotle.

The use of precious metals as coins, —that is, universally exchangeable evi-

dences of value,—was a natural result, but some progress in systems of government and in mechanical skill was necessary before a true coin could be produced. The use of coined money cannot be traced back earlier than 1000 B. C.; prior to that time bars or even irregular masses of the precious metals were used, the value being ascertained by weight. As refining processes were crude and the temptation to adulterate very great, we may suspect that there was much deception in these operations. Nevertheless, we find that the coins of ancient times are of fair purity. With a view of securing some details in regard to the actual state of ancient coinage, the writer enlisted the aid of Mr. Eckfeldt, of the United States Mint, who furnished the following data:—

For about three centuries Roman money consisted of bronze (copper and tin), at first cast, but afterward stamped when other metals came into use. In the year of Rome 487 (286 B. C.) silver was introduced into coinage and gold sixty years later, though it is believed that the gold coinage was trifling prior to the conquests of Julius Cæsar. In his time bronze began to be displaced by copper and brass. The brass disappeared about the close of the third century A. D., and copper alone was used for inferior coinage. The gold coin was maintained at almost purity (990 to 995) from first to last. The exceptions in the mint collections are in the instance of coin of Michael I. (A. D. 813), who, besides a coin of good weight and fineness, issued one very inferior in both respects, the fineness being not above 600. (It is to be noted that this coin may have been spurious.) In 1067-1081 gold coins of inferior quality were issued by Michael VII., Romanus IV., and Nicephorus III. The standard was restored by the next prince, Alexius I.

The silver coins down to the reign of Augustus were also intended to be, and were considered, pure, and are found to be 950 to 985. In the ensuing reigns there was a constant downward tendency. In the coinage of Nero we find the fineness was 820; from Vespasian to Hadrian, from 780 to 850. The very base silver began with Septimus Severus (A. D. 200). The coins contained not more than 40 to 50 per cent. of silver, the alloy being copper with a portion of tin to preserve the colour. A permanent reform dates from the age of Diocletian in the early part of the fourth century. Silver of from 910 to 960 was used in all the coins from that time down through all the decline of the Empire.

The above data as to fineness are from the actual tests at the United States Mint; by assay in the case of coins not valuable, by specific gravity when the pieces were too valuable to cut. The specific gravity method is very close for gold and a good approximation for rare silver pieces.

For over a thousand years mankind declared and believed that gold and silver could be artificially produced, and innumerable searchers have laboured on this problem. These workers have not been wholly within the class of metallurgists or what we might call scientists, but all ranks and callings have contributed contingents. The general impulse which we designate as alchemy remained influential until the beginning of the eighteenth century, and was so widespread that it deserves consideration by a student of social science. While it is probable that in the more ignorant ages a larger number of people believed in incantations and ghosts than practised true alchemy, yet the public profession of the latter was much more frequent than the public profession of supernatural powers. The history of alchemy has indeed less significance for chemistry than for the history of culture.

The belief in transmutation was promoted by the observation of cases in which the appearance of gold and silver could be imparted to baser metals. For example, copper alloyed with zinc assumes the ordinary colour of gold. Treated with certain arsenical substances it assumes a silver-like appearance. Moreover, the doctrine of Aristotle, that substances differ not because of different composition, but by reason of difference of properties, necessarily encouraged the transmutationists. It was in this spirit that one operator dis-

tilled mercury seventeen hundred successive times in hopes of driving out from it the liquefying principle and thus obtaining the solid silver.

This ignorance as to the details of chemical composition also led to another misunderstanding. Mine waters containing copper compounds (the existence of copper as such in the water was not recognised) would, by the action of iron, deposit the copper and the iron would dissolve. We have no difficulty to-day in comprehending the nature of the action, but there was a time when it was believed to be a transmutation, and in alchemical language was expressed as being due to Mars (iron) having laid off his armour and decorated himself with the garments of Venus (copper).

In passing, it may be noted that some of the tendencies in modern thought seem to be toward the older views. The atomic theory, which has held an authoritative position in chemistry and physics for a century, has been, of late years, subject to attack from several points of view, and some work lately accomplished may foreshadow transmutation. Within our own time one substance universally considered an element, didymium, has been split into two components, respectively neodymium and praseodymium. Several contributions have been published lately indicating that before long one of the principal elements of the Welsbach mantle, thorium, will yield up the ghost in the same way. Claims for the identity of phosphorus and arsenic, though stoutly defended by a certain chemist, have not been generally allowed.

A considerable manuscript literature relating to so-called "alchemy" exists in some of the libraries of Europe, and, as already noted, the painstaking labours of Berthelot have thrown these open to general study. One point is especially worthy of note; the authorship of many of the manuscripts is fictitious. It was a common trick to attach to an essay the name of some great man, philosopher, ruler, or ecclesiastic. The sacred names of biblical literature have not escaped. One alchemist claims to give us Moses' chemistry and another ascribes his book to John the Archbishop, possibly the same person regarded by many modern critics as the author of the fourth gospel.

It has been a widespread belief among educated people for many years that the Arabian philosophers, during the period of Islam's control in Southern Europe, carried forward in many ways scientific work in chemistry, but it is now known that this view is erroneous. The manuscripts purporting to be Latin translations of works of Arabian philosophers are forgeries of a much later date; the genuine manuscripts are mostly mystical discussions of no practical value. The most ancient actual record bearing on practical metallurgy is a papyrus manuscript now in the library at Leyden, Holland, and regarded as having been written toward the close of the third century A. D. It is not improbable that it is one that escaped the general destruction which the Roman Emperor Diocletian ordered about A. D. 290 against all works on alchemy and magic. The Emperor's object was, as he stated, "that no one should be able to enrich himself by this art, nor to secure by it riches which should render possible revolt against the Romans." I recall here the fact reported by Mr. Eckfeldt that it was Diocletian who restored the silver coinage to the highest standard. The text of the manuscript contains over one hundred receipts for operations of purification, alloying, gilding, and some for fraudulently imitating precious metals. Unfortunately many terms are of uncertain meaning, and the translations, therefore, are in doubt. It would be tedious to present even a moderate number of those recipes; a few illustrative ones may be quoted, and in such quotations I rely entirely on the French text by Berthelot. For example, the operation of cupellation is fairly described under the title, "How to purify silver and render it brilliant." Take one part of silver and equal part of lead, place in a furnace and keep it fused until the lead has been consumed; repeat the operation several times until it becomes brilliant.

A recipe for gold solder, over 1600 years old, was,—Copper 4 parts, elec-

trum 2 parts, gold 1 part; melt the copper first, then add the electrum, then the gold. Electrum, as already mentioned, is the term applied to a native alloy of gold and silver.

All will probably be at least a little interested in Moses' recipe for making gold. This is found on a manuscript in the St. Mark library at Venice. The text is a fair sample of the indirectness and insincerity of these true alchemical recipes. Take copper, orpiment, sulphur, and lead; triturate the mixture with oil; roast until the sulphur is removed; withdraw the mixture from the fire and mix with it three parts of gold; reheat it and you will find that it has all changed into gold, with the aid of God.

This is, of course, merely a gold alloy of inferior value, which possibly has a good colour.

The ancients, however, were not wholly occupied with transmutation or fantastic procedures. A skillful metallurgy was developed along some lines. Working in lead, for example, became an important art, especially the making of lead pipe for conveying water. Not long ago some excavations in Rome brought to light a lead pipe nearly a foot in diameter for supplying the palace of Domitian. Pipe of smaller size has been dug up by the hundredweight in various parts of the Roman Empire.

Copper, by reason of its rather frequent occurrence in the free state and also its malleability, ductility, and readiness to form alloys, found early use, and was for a long while employed for many purposes for which iron has since been used. The Trojans were equipped with brass weapons. Agricultural and mechanical implements were often made of the same material. In the English Bible we find reference to Tubal-Cain as the first artificer in brass and iron, and a marginal note gives for brass the alternative reading "copper." Brass was probably often obtained by the joint reduction of ores of copper and zinc, and not made, as in our day, by careful alloying of the free metals. The conditions of antiquity in respect to metals have been regarded by some as paralleled by the case of the aborigines in the country at the time of its discovery, for these had copper implements, but no iron ones. Numerous examples of bronze stopcocks and other plumbing accessories are found in the Naples Museum among the Pompeiian collection.

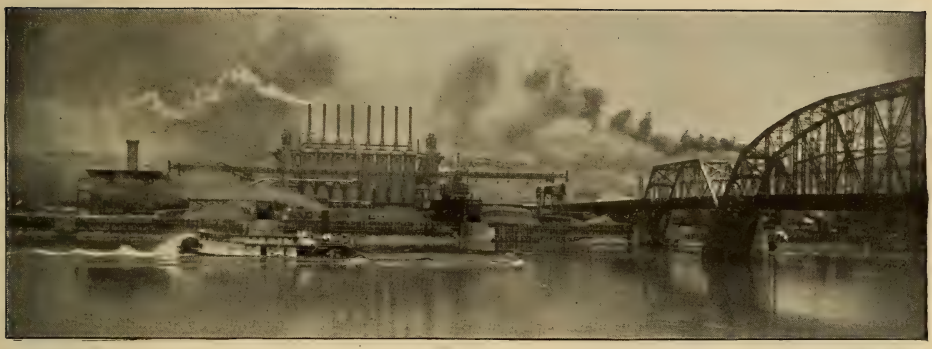


FIG. I.—THE CARRIE FURNACES OF THE CARNEGIE COMPANY

HANDLING ORE AT A BLAST-FURNACE

SOME DETAILS OF A TYPICAL AMERICAN PLANT

By W. L. Cowles, C. E.

IT is recognised in all branches of industry that human labour constitutes the larger portion of the cost of production, and it is the aim of economists to devise machinery which shall, in as many directions as possible, replace this labour. In the making of steel the substitution of mechanical appliances for manual labour has taken place all along the line, from the first removal of the ore from its bed by steam shovels to the automatic rolling, cutting to length, and loading on cars of the finished rails, and at every stage of the process when a man has been replaced by a machine, if the latter has been wisely designed, well made, and properly operated, reduction in cost has been the result and a cheaper final product has been attained.

An interesting chapter might be written descriptive of the mining of the ore and its transportation to the furnace yard with the ingenious appliances for loading and unloading the ore vessels on the Great American Lakes and the transfer of the ore into cars, the quarrying and crushing of the limestone, and the production of the coke by the most modern methods; but the writer will assume that all this has been done, and that the various materials have arrived in train-loads at the furnace yard. For the purpose of this article, and as an excellent example of modern methods, he has selected the ore and limestone-handling plant recently installed at the new Carrie furnaces of the Carnegie Steel Company, Ltd., at Rankin, Pa., forming part of their Homestead Works, the larger portion of which machinery was designed and constructed by the Brown Hoisting Machinery Company, of Cleveland.

The furnaces occupy a large tract on the north side of the Monongahela River opposite to the Homestead mills and extending from the river back to the Pittsburgh & Lake Erie and Baltimore & Ohio railroads, the arrangement of the plant being shown in the general plan on page 159, only those tracks, however, having been included which constitute an essential part of the ore-handling system.

A general view of the entire plant is shown in Fig. 1, the bridge at the right

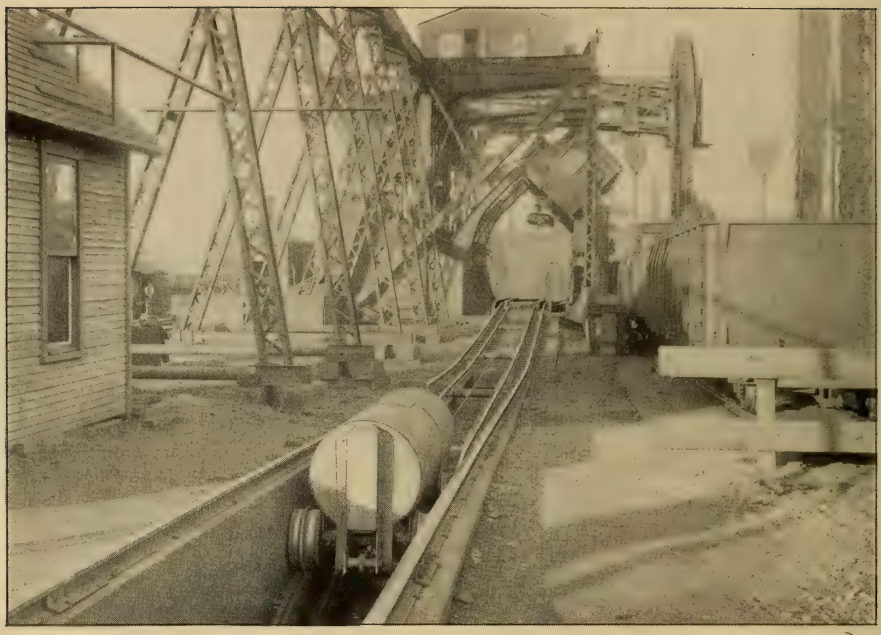


FIG. 2.—THE "GROUND HOG." THIS PUSHES THE LOADED ORE CAR ONTO THE DUMPER SHOWN IN FIG. 4

being a double-track structure belonging to the Union Railroad Company, built for the express purpose of connecting the furnaces with the rolling mills and having a special "hot metal" track, used for conveying molten iron in ladles mounted on trucks from the blast-furnace direct to the open-hearth steel furnace. The coke is brought in from tracks not shown on the general plan to the "elevated coke tracks," seen in front of the row of stoves, from which it is dumped through the car bottoms or unloaded by hand into special coke bins, two in front of each furnace, and what follows will be understood as applying only to the handling of the ore and limestone.

The first operation after the arrival of the trains in the yard is to unload the cars, and this is accomplished by means of a tipple or car dumper, shown in Fig. 4. It is essential to the operation of this dumper that the track on which the car moves while entering and leaving it should be laid on special grades, these being designed to suit the plan of operation to be described. Trains are first made up of cars selected with reference to the relative quantities and kinds of ore and limestone required, and are switched onto the dumper tracks, the locomotive pushing the train on one track toward the dumper until all the cars are beyond the apex and are on the first descending grade, when all brakes are set and the locomotive uncouples and runs back to push up the train on the other track. These two tracks unite at a point near the bottom of the grade and just before they reach the pit, which is built under the track. Reference to Fig. 3 will help to make this clearer.

In the pit is placed the disappearing car, or "ground hog," as it is sometimes called,—a small but strongly built car of peculiar construction, shown in Fig. 2, in which the construction of the pit may also be clearly seen. This view is not taken from the Carrie furnace plant, but is used to illustrate the construction. The pit is of such width that the standard-gauge track can be laid on top of its walls, while the "ground hog" runs on a narrower track de-

scending into the pit. A wire cable, attached to the end of the "ground hog" and supported by rollers placed between the rails, passes to the dumper, where it leads to a drum in the engine house, whereby the operator can cause the "ground hog" to move up out of the pit and toward the dumper.

The brakes of the first car of the train are now released and the car starts down the grade by gravity and is carried by its momentum to a point beyond the pit, where its motion is checked by the ascending grade between this point and the dumper. As it passes the pit the "ground hog" rises and follows, catching the car as its motion slacks and pushing it on up the grade and onto the section of level detached track which forms the floor of the dumper. When the car has been properly placed on the floor of the dumper, the "ground hog" is allowed to run back into the pit, ready to repeat the operation with the following car.

The operation described above is that which was designed for this plant and is similar to that used with complete success in another location; but it was found, after using it for a while, that local conditions made it impracticable, for the reason that, as the yard room was limited, the extent of track which could be devoted to the incoming cars was insufficient, and the permissible grade was not great enough to insure rapid handling. The limited number of cars which could be put on the grade

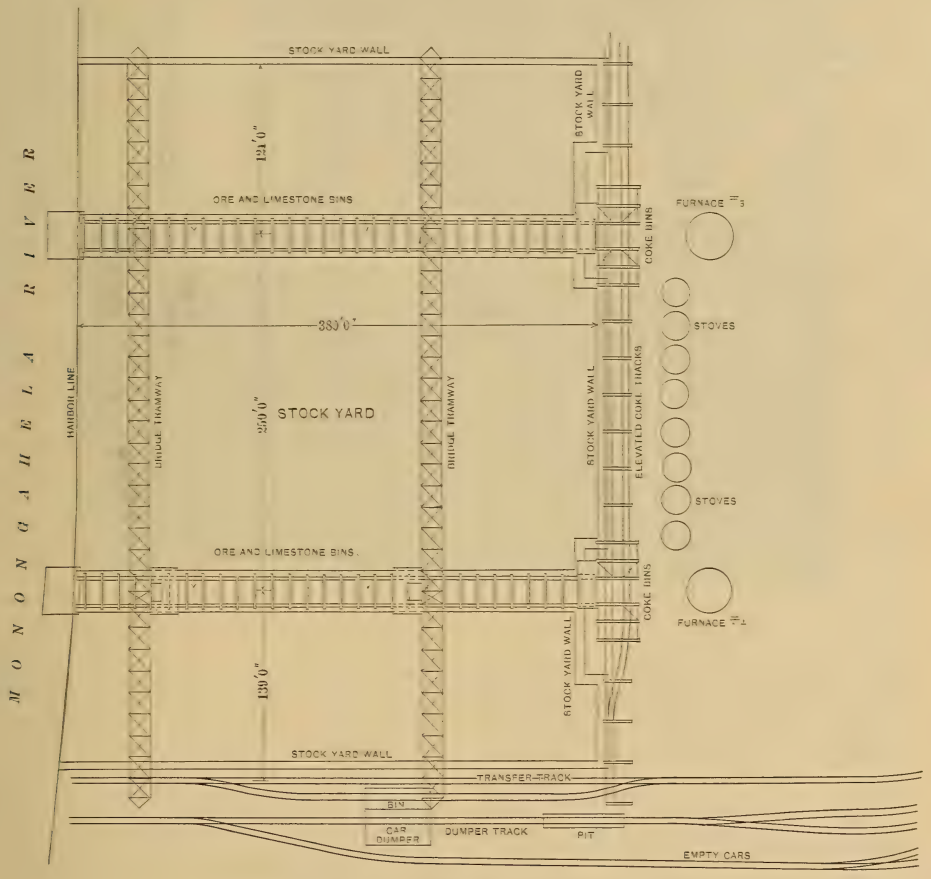


FIG. 3.—A PLAN OF THE BINS AND ORE-HANDLING TRACKS

FIG. 4.—THE CAR DUMPER LIFTS THE CAR BODILY AND OVERTURNS IT

made it impracticable to use the locomotive for any other purpose while these cars were being dumped, as might have been done had the grade been longer, and it was, therefore, determined to remove the "ground hog" and use the locomotive constantly for pushing the cars onto the dumper, and this method has been used ever since.

The car dumper consists of a section of detached track, referred to previously, supported by massive frames in the shape of an irregular U, the whole forming a cradle of a size sufficient to hold the largest gondola or steel ore car. At the top of one side of this cradle is a 10-inch horizontal shaft, about which it may be made to revolve, and to the other side near the bottom are attached wire cables leading to drums in the engine house above, whereby the cradle, with the car, may be lifted and turned about the shaft. The engine house is supported by substantial columns, heavily braced, and designed to effectively resist the varying stresses which come upon them during the revolution of the cradle. Electric motors are employed to operate the drums, and are so combined with efficient band brakes that the entire mechanism is easily controlled by one operator. The engine is assisted by a counterweight attached to the cradle by means of wire cables passing over sheaves in the upper portion of the fixed framework, and so adjusted that it helps

to lift the cradle until its centre of gravity with loaded car is over the horizontal shaft, and works to retard the motion after it passes that point.

To hold the car rigidly in position, horizontal and vertical clamps are provided, operated by hydraulic pressure and having such a range of motion that any size of car may be dumped with facility. When the car has been firmly clamped, the cradle is lifted and overturned, as shown in Fig. 4, until the contents, guided by a steel apron, extending the whole length of the car, are emptied into a bin having a capacity of about two large carloads. The cradle and empty car are then returned to their normal position, the clamps are released, and the following loaded car coming onto the dumper pushes off the empty one.

The track leading from the dumper and upon which the empty is pushed is on a down-grade. This is followed by a level portion which is occupied by a spring switch, set for the return track, and beyond this again is a much steeper ascending grade. The relation between these grades is such that the momentum acquired by a car in descending the grade from the dumper is sufficient to carry it across the level portion, through the spring switch, and up the last grade just far enough to fairly pass the point of the switch. The momentum again acquired as it descends the last grade, returning, will carry it around the curve, by the dumper, and down the track to the storage yard for empties. The amount of energy lost by friction depends mainly upon the comparative lubrication of the journals, and to prevent any possible overruning of the car a buffer is placed at the end of the track; but it is rarely touched by the car, which usually comes within a foot or two of it, when its energy is entirely absorbed and it starts on its return trip.

The car dumper is capable of handling thirty 60-ton cars per hour, or 18,000 tons per day of ten hours. The working capacity is limited by the ability of other appliances to remove the material from the bin, which at present is deficient. They are ample, however, to supply the present needs of the plant, which can be greatly extended, if desired, without requiring any increased capacity in the dumper. The capacity mentioned has been reached in practice, sixteen cars having been dumped in thirty-two minutes, when the bin was full and it became necessary to cease operations.

The dumper bin, shown in Fig. 4, is constructed of steel plate and is divided by partitions into eight compartments, each terminating below in a chute which is closed by a revolving gate. The partitions are double, the two sides being far enough apart,—about 10 inches,—to provide room for the mechanism which operates the gates. This mechanism, shown in Fig. 5, consists of a series of large gears, a pair for each gate, to the rims of which are attached throwing bars, the other ends of the latter taking hold of the corners of the gates, which are thus given an oscillating motion, opening and closing the chute as the large gears revolve. The large gears mesh into corresponding pinions, which are strung on a continuous shaft extending the whole length of the bin and attached to it by clutches, so that any gate may be operated at will.

A special electric motor at one end of the shaft furnishes the power, and the controller is connected to a small shaft, also extending the whole length of the bin and provided with levers, thus enabling the operator at any point to control the motor and operate the several clutches at the same time. The compartments of the bin are equally spaced and at such distances apart that when a bucket car is properly placed below each alternate chute will be over one of the buckets, which are then easily and rapidly filled without changing the position of the car.

The bucket cars, made in pairs, coupled, in order that they may easily pass around curves, are shown in Fig. 7, with three loaded 10-ton buckets, as they come from the dumper bin. Each car has its own motor, but both are controlled from the end of one car which is provided with a cab. These cars operate upon a straight main track, parallel

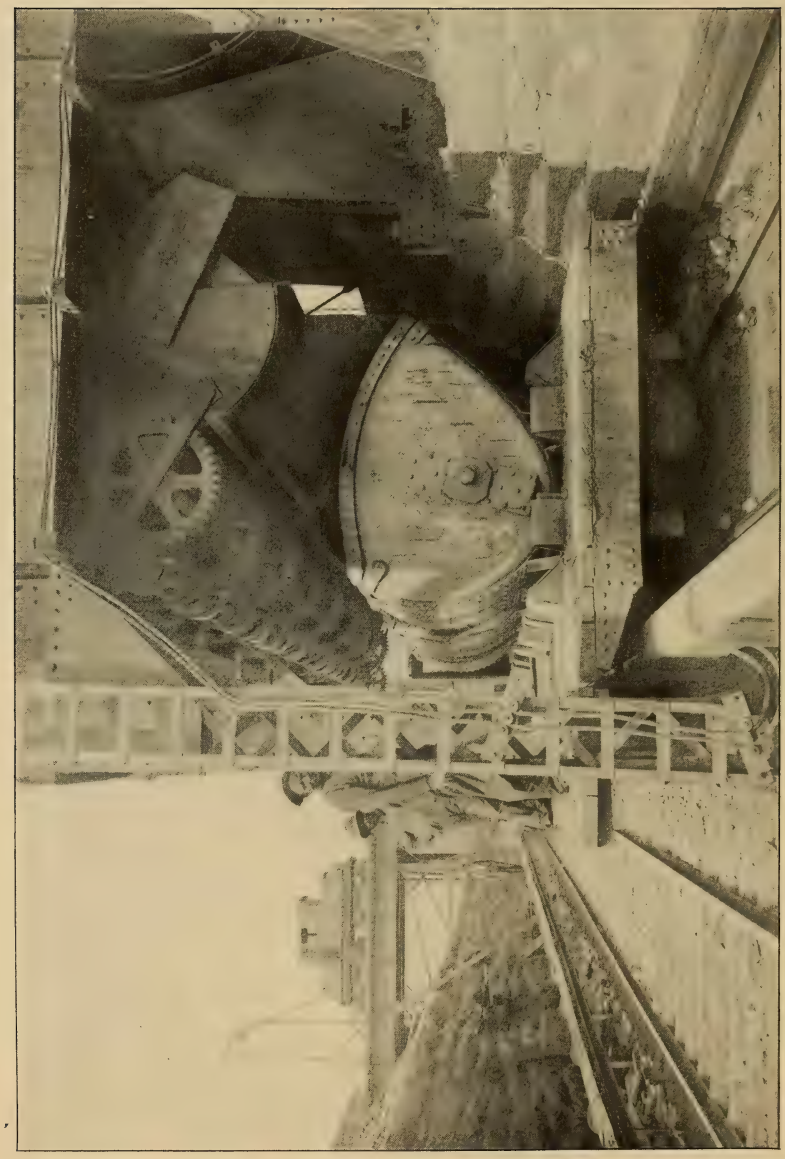


FIG. 5.—THE GATE-OPERATING MECHANISM FOR THE DUMPER BIN

with and close to the wall of the stockyard, designated on the general plan as the "transfer track," and upon a shorter side track passing under the dumper bin. The side track is connected at each end with the main track by spring switches, so set that the cars will first run through the switch and then, returning, follow the proper track, thus continually making the circuit without requiring any hand switching.

In Fig. 9 the electric contacts are more clearly shown. The conductors consist of square iron bars in pairs, supported and protected by steel conduits, seen in all of these views, and are placed on the right-hand or left-hand side of the track, as required by circumstances. Contacts are provided on both sides of the cab car to suit this arrangement. When the three buckets under the dumper bin have been filled, the cars upon which they rest are run to the end of the transfer track to the left, then back upon the straight portion to a point beneath one of the bridge tramways, which has already been placed over the spot where it is desired to deposit the ore.

It will be noticed that in addition to the three loaded buckets shown in Fig. 7 space is provided on the car for a fourth bucket. While the cars just referred to are approaching the point where they are to stop, those preceding are moving away, and the last bucket taken from these preceding cars is being conveyed by the bridge tramway to the proper spot and dumped, and as the new cars stop, with the vacant space under the tramway, the empty bucket is returned and lowered to the car, as seen in Fig. 6. The detachable bail is then transferred from the empty bucket to the next loaded one, which is lifted, carried away, dumped, and returned. The process is repeated with the second loaded bucket, and as the last one is lifted the cars move away with the three empty buckets, while the next pair of cars with three loaded buckets and a vacant space takes its place and the operation is repeated.

In Fig. 8 is shown a general view of the works, wherein the two bridge tramways mentioned above may be seen mounted upon the bins upon which they travel. These bridge tramways are duplicates, except that the piers with their engine houses are made right and left, with the engine house in each case placed on the side of the pier farthest from the end of the track, so that the buckets may be dumped as near the ends of the stockyard as possible.

This arrangement is more clearly shown in Fig. 10, in which also the general construction of the pier, engine house, and cantilever may be noted. Each bridge tramway consists of a central span, 250 feet long, supported at one end by a steel pier, 62 feet high above the level of the stockyard, and at the other end by a shear leg of the same height. From the end supported by the pier a cantilever (Fig. 10), 160 feet long, extends over a portion of the stock yard and the transfer track, and from the other end a similar cantilever, 148 feet long, extends to the other side of the yard, the entire structure having thus a total length of 558 feet, or a total trolley travel of about 540 feet.

The pier consists of two pairs of steel posts, 15 feet apart, the posts of each pair uniting at the top and having a spread of 19 feet 6 inches at the bottom. The bottoms of these posts rest upon a frame of steel girders, beneath each of the four corners of which are double trucks. The shear leg consists of a pair of very heavy steel posts, uniting at the top at a point considerably above the stringer level of the bridge tramway and having a spread at the bottom of 20 feet. The feet of these posts are connected by a heavy strut and rest on two sets of equalised double trucks. The entire structure runs upon tracks laid upon the tops of the parabolic ore and limestone bins, which will be described later. The motive power is furnished by two 135-horse-power electric motors, with necessary drums, clutches, and brakes, installed in the engine house mentioned above. This engine house is located on an extension of the frame which carries the pier and is supported by two more sets of double trucks. The four sets of trucks under the engine house are con-

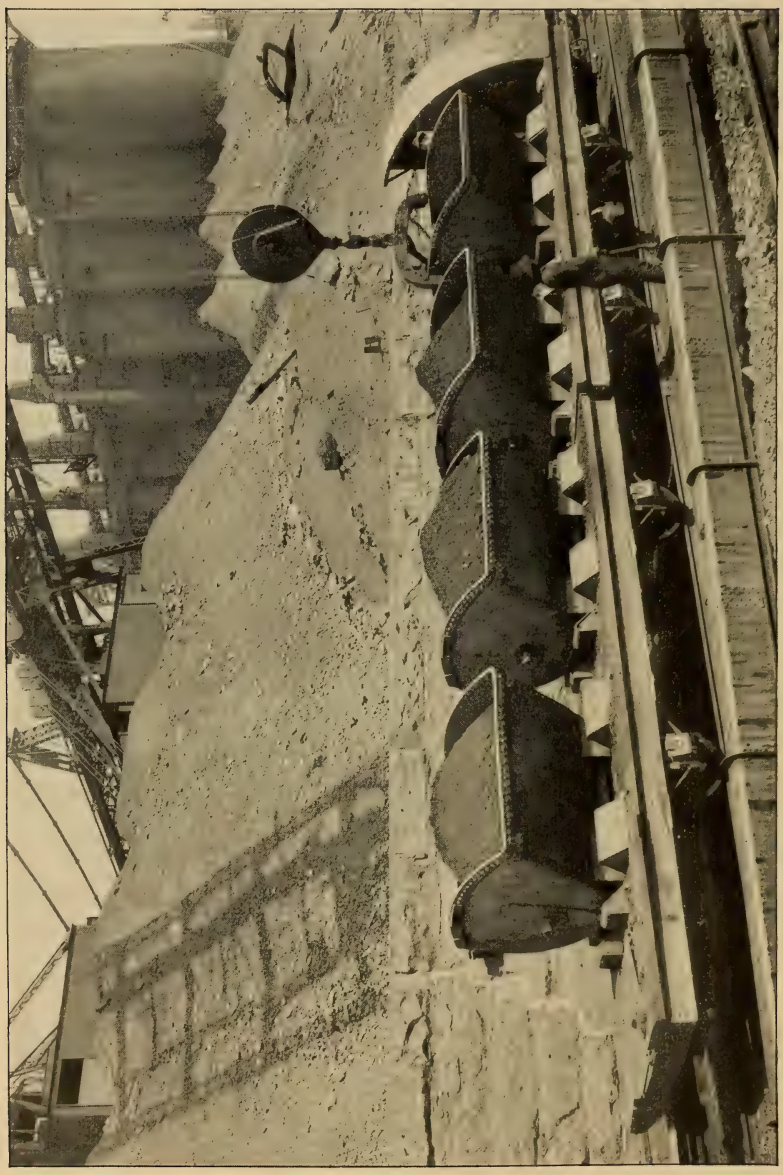


FIG. 6.—THE OVERHEAD TRAMWAY CARRIES OFF AND DUMPS THE BUCKETS

nected with the engine through a system of shafts and gears, so proportioned that a speed of 75 to 100 feet per minute is developed. To impart corresponding motion to the shear leg, connection is made with the engine through a similar system of shafts and gears, carried to the top of the pier, across the central span, and down the shear leg to the supporting trucks.

To provide for loss or irregularity of motion, through torsion of the long shafts or possible slipping of wheels, resulting in a change in the relative positions of the pier and shear leg, provision is made for the skewing of the bridge to the extent of 1 foot to 9 feet in length. To accomplish this the bridge is free at the pier end to swing about a vertical pin passing through the centre of the pier cap, the bearing plates of the main compression chords resting on nests of conical steel rollers at the top of the pier, while at the shear leg end a ball casting on the top of the shear leg supports a socket casting, through which passes a 4¾-inch steel saddle rod, carrying at its ends a heavy yoke, upon which rest the chords of the bridge.

It is evident that any such skewing of the structure will result in a shortening of the perpendicular distance between the pier and the top of the shear leg, and to provide for the tilting of the latter so occasioned, ball and socket bearings are introduced between its feet and the supporting trucks. The central span is of the inverted bowstring type, with straight top chords and parabolic bottom chords. The construction of the cantilevers is clearly shown in the cuts, their bottom chords being continuations of the top chords of the central span. These compression chords and the main posts over the pier and shear leg are constructed of steel channels and plates, but all other posts and braces are of extra heavy gas pipe of varying sizes. The tension chords of the central span are of wide steel plates, in horizontal position, in order to reduce the wind pressure to a minimum; but those of the cantilever and their back stays are of medium steel eye bars, while all tension diagonals and wind bracing are of double refined iron.

FIG. 7.—THE BUCKET CARS, MADE IN PAIRS, COMING FROM THE DUMPER BIN

Between the trusses of the bridge are transverse floor beams, supporting two lines of stringers suspended below them, and upon these stringers runs a trolley from end to end of the bridge, the pier and shear leg being so designed that there is free room for the passage through them of trolley and bucket, all bracing being omitted at those points. This trolley is quite different from the ordinary type used in these machines,

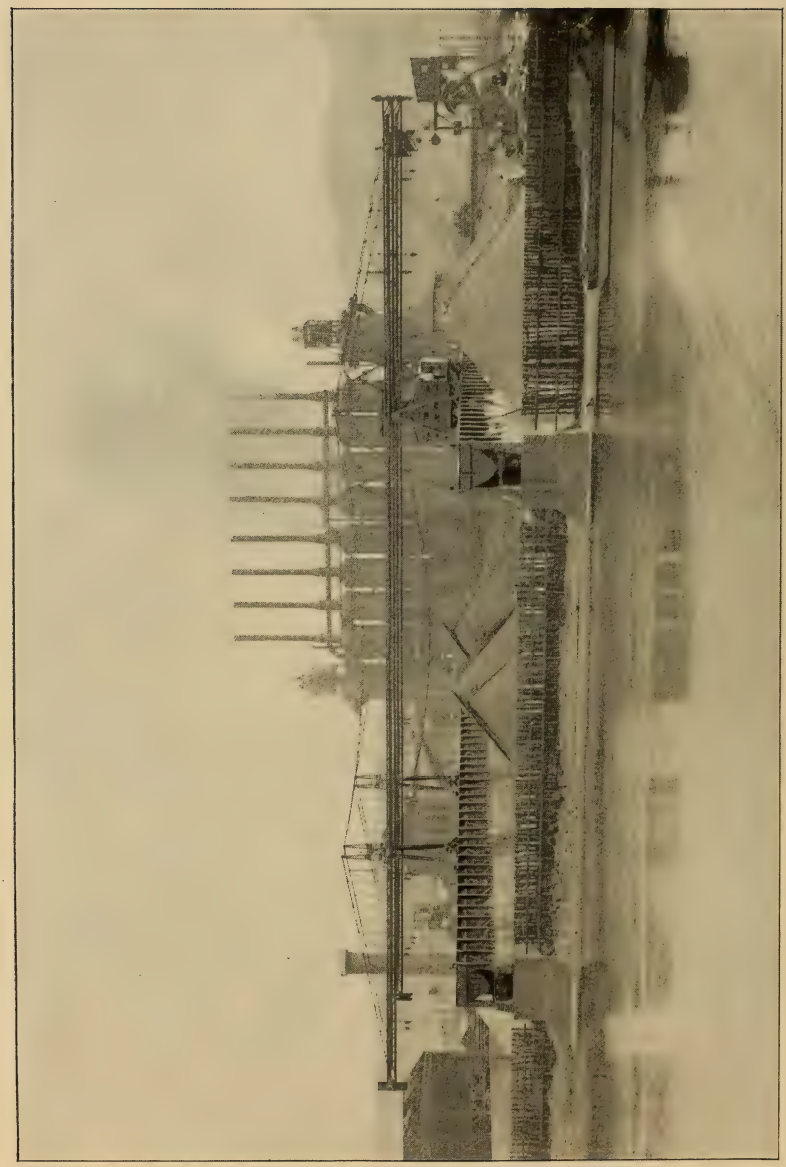


FIG. 8.—ANOTHER VIEW OF THE CARRIE FURNACES, SPECIALLY ILLUSTRATING THE TWO BRIDGE TRAMWAYS AND THE ORE BINS UPON WHICH THEY TRAVEL

in which the hoisting rope leaves the main sheaves centrally and runs free to the ends of the structure In this case the length from end to end is so great that the sag of the rope, when the trolley is at one end, would cause it to drag on the ore pile, and in order to prevent this the rope, which, on account of the high stress, is made double, after leading off from the main sheaves, is carried by tilted deflecting sheaves to the sides of the trolley, one part to each side, whence it leads out in each direction over a series of sag carriers suspended from the trusses and far enough apart to permit of the free passage between them of the trolley and suspended load.

The trolley will pick up the rope as it passes over a pair of sag carriers, and, as it proceeds, the rope settles again into its place. These sag carriers consist of small sheaves supported by depending frames, and, together with the trolley with its detachable bail and the end sheave supports, are clearly shown in Fig. 10. Despite the precaution taken to guide the rope into the sag carrier as it settles down from the trolley, it was found that it would occasionally flop over the side. To prevent this the inner guard of the sag carrier was increased somewhat in length, and a steel wire rope was stretched from tip to tip throughout the entire length, with the result that when the rope flopped out of its guide its own tension caused it to follow the guard rope back over the tip and into its carrier sheaves.

The hoisting rope is of ⅞-inch plough steel, double, as mentioned above, and is attached to a drum in the engine house, forming part of the engine already referred to. Around this it is wrapped several times to give it a certain amount of frictional adhesion. From the drum it passes over a series of deflecting sheaves to the top of the pier, thence along the bridge to the end of the cantilever, where it leads around a sheave in the large sheave support seen in Fig. 10, and back to the trolley. Here it descends to the block which supports the bucket, and, rising again to the trolley, passes through it and over the sag carriers to the end of the other cantilever, where it is attached to a spring buffer.

It is evident that if the hoisting drum is held by a brake after lifting the bucket to any required height, this height will be maintained if the trolley is moved in either direction along the stringers which carry it, the hoisting rope merely running through the trolley and block as

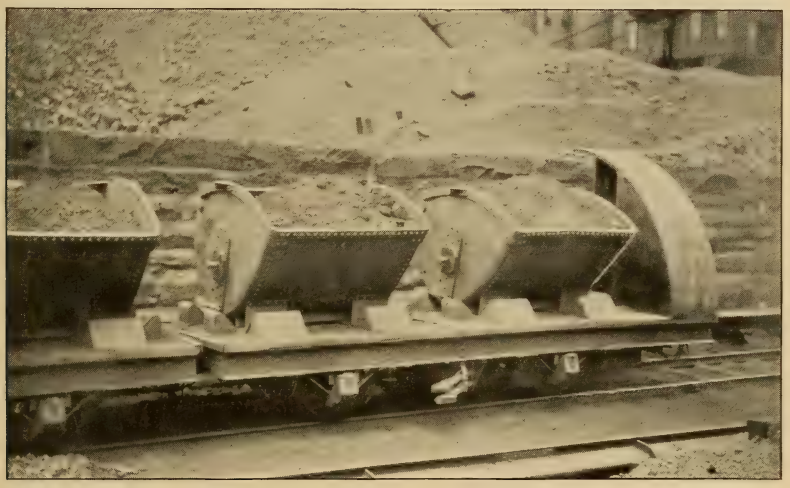


FIG. 9 —CURRENT FOR PROPELLING THE BUCKET CARS IS TAKEN FROM A LATERAL CONDUCTOR THROUGH THE CONTACTS SEEN AT THE SIDE

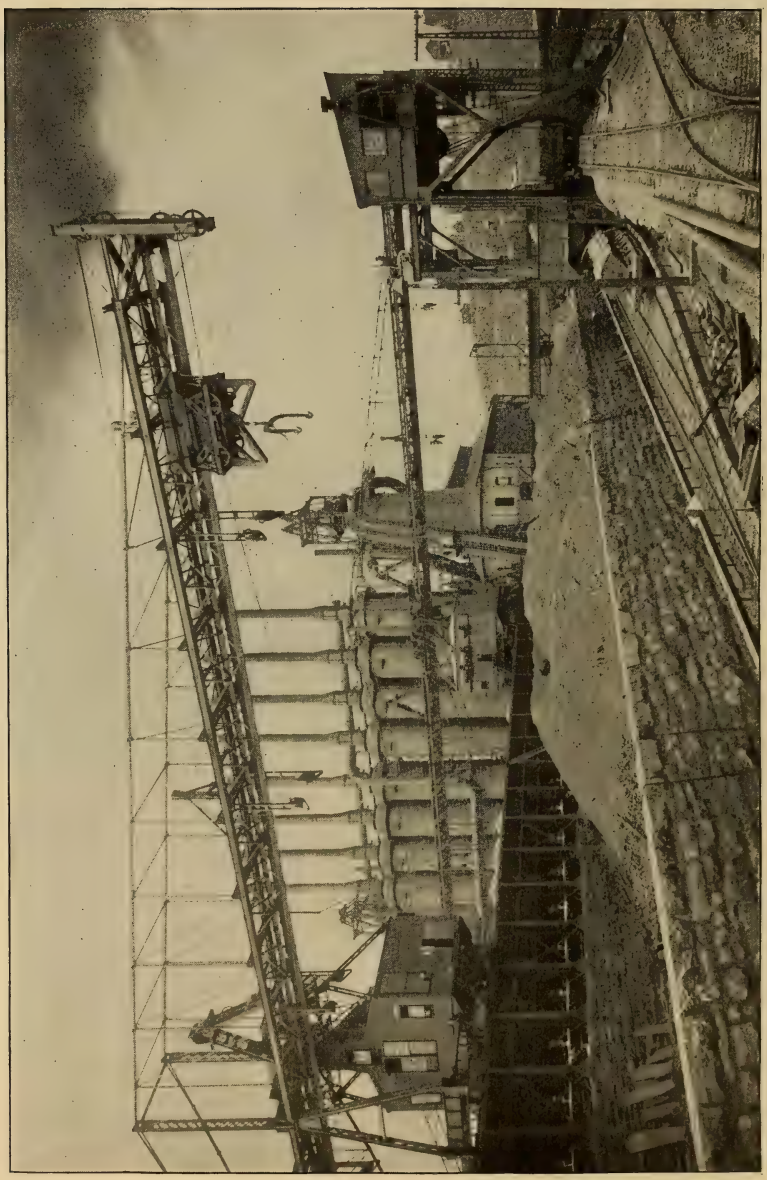


FIG. 10.—SOME DETAILS OF THE BRIDGE TRAMWAY MECHANISM ARE HERE MORE CLEARLY SHOWN

the former moves. This operation is called "racking," and is effected by means of two "racking ropes," also of ⅞-inch plough steel, and double, one of which is attached to one end of the trolley and leads to the end of the cantilever, around a sheave and back to the top of the pier, while the other is similarly disposed in the opposite direction.

FIG. 11.—A SHOVEL BUCKET FOR CARRYING ORE FROM THE STOCKYARD

From the top of the pier they lead over a system of deflecting sheaves, like the hoisting rope, to a pair of drums in the engine house. These drums are geared together so that they turn simultaneously, but in opposite directions, one rope winding off as the other winds on. The trolley, with its suspended bucket, can thus be rapidly moved to any point within the limits of the trolley travel, and as the entire bridge tramway can travel on its tracks to any point in the other direction, the whole area of the stockyard is completely served. The speed of hoisting a 10-ton bucket of ore, or a total weight of about 13 tons, is from 250 to 300 feet per minute, and the speed of racking is from 800 to 900 feet per minute.

The bucket can be dumped either in one of the bins which support the bridge or on the stock piles on either side of and between the bins by means of a simple dumping device, consisting of a piece of heavy gas pipe suspended from the truss by wire ropes, like a trapeze. This gas pipe can be placed at any point and at such a height that, as the bucket reaches it, it trips a latch and the bucket dumps by gravity. To dump into a bin, the trolley is stopped over the desired point and the bucket is lowered until a similar trapeze, properly placed, trips the latch. The construction of the bucket is such that, upon dumping, the entire contents fall vertically without any side scattering whatever.

The trolley, with its bucket, is capable of making twenty-five to thirty-five trips per hour, according to the distance which it has to travel, or an average of thirty trips per hour, giving a capacity of 300 tons per hour for each bridge tramway. It is impracticable, however, to maintain this capacity through an entire day, as some time is necessarily lost in oiling, adjusting the dumping trapeze, and changing the position of the bridge tramway for dumping in different parts of the yard. During the summer season the bins are ordinarily filled by buckets direct from the car dumper, the excess of ore received over current requirements being deposited in the stockyard. When navigation closes in the winter ore still comes in from the Lake docks, where great quantities are stored; but in the worst weather it becomes impracticable to draw from this source, and, no ore being received from outside, the

FIG. 12.—A FRONT VIEW OF THE BUCKET

FIG. 13.—ILLUSTRATING THE SKIP-DUMPING PRINCIPLE

bins are filled from the stockyard. This is accomplished by the use of a shovel bucket, shown in Figs. 11 and 12, which is attached to the block in place of the detachable bail. This shovel bucket is lowered to the base of the pile of ore and the trolley is moved forward until the hoisting rope leads back at an angle of about forty-five degrees, when the trolley is held in position by a brake on the racking drums while the hoisting drum is started, with the result that the bucket fills with ore as it drags up the pile and is then carried to the bin and dumped.

The engine runs continuously and is not reversing, the several operations of digging, hoisting, and racking, and the travelling of the structure being accomplished by suitable clutches and brakes, manipulated by one operator who is located in a small house above the engine house, from which he commands a view of all portions of the plant. The

brake used for holding the trolley is a powerful one, operated by hydraulic pressure, but it is not sensitive enough for the ordinary use of controlling the motion of the trolley while carrying a load. An auxiliary mechanism is, therefore, provided, whereby the same brake is operated by the foot, and the motion is easily regulated. An indicator in the operator's house, showing the position of the bucket at any moment, enables him to dump it at any desired point with accuracy.

The bins, upon which are laid the tracks which carry the bridge tramways, are parabolic in form and are suspended from longitudinal plate girders of special construction. These are triangular in cross section, having two webs meeting at the bottom where they have a common bottom flange, and separated at the top by a distance equal to the gauge of the track which they support, but connected by a wide plate which, with the connecting angles, constitutes the top flange. The inclinations of the two webs from the vertical are equal and are such that the outside web is tangent to the parbola of the supported bin which is connected to it through an extension of the web below the bottom flange. This construction involves a closed section, and holes are, therefore, provided in the outside web to permit painting of the interior. The longitudinal girders are supported at frequent intervals by rigid frames composed of heavy plate-girder columns and deep transverse girders, the latter taking up the horizontal component of the pull from the bin plates.

The space between the bottom of the transverse girder and the bottom of the bin is filled in by partitions at desired points in order to separate the limestone and the different kinds of ore. In each section, between any two columns, two chutes are provided at the bottom, one to deliver to the right and one to the left. These are closed by gates revolving about a horizontal axis and operated by steam power, each gate having an independent steam cylinder and valve.

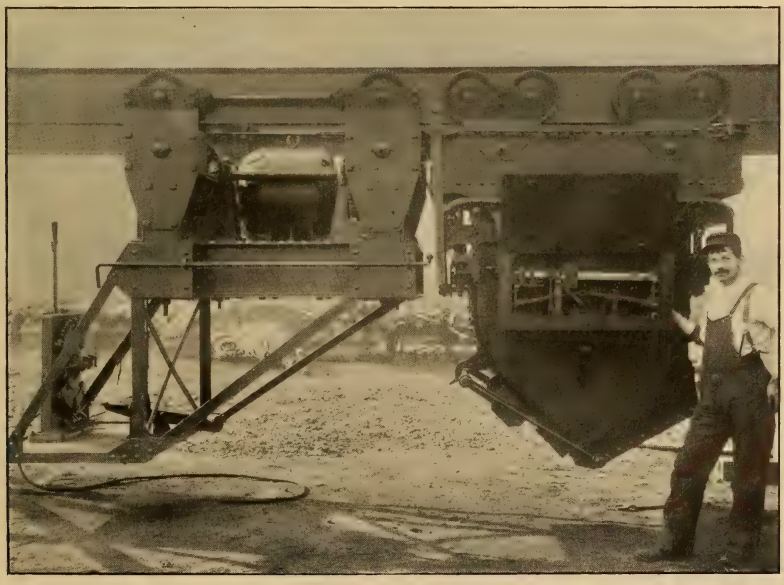


FIG. 14.—AN ELECTRIC LOCOMOTIVE AND LARRY SUSPENDED FROM I-BEAM TRACKS THE LARRY CARRIES ORE FROM THE STOCK BINS TO THE FURNACE SKIP

Below each bin, and at every pair of posts, is a cross beam supporting a suspended double track of I-beams, upon the bottom flanges of which travel electric locomotives and larries, as shown in

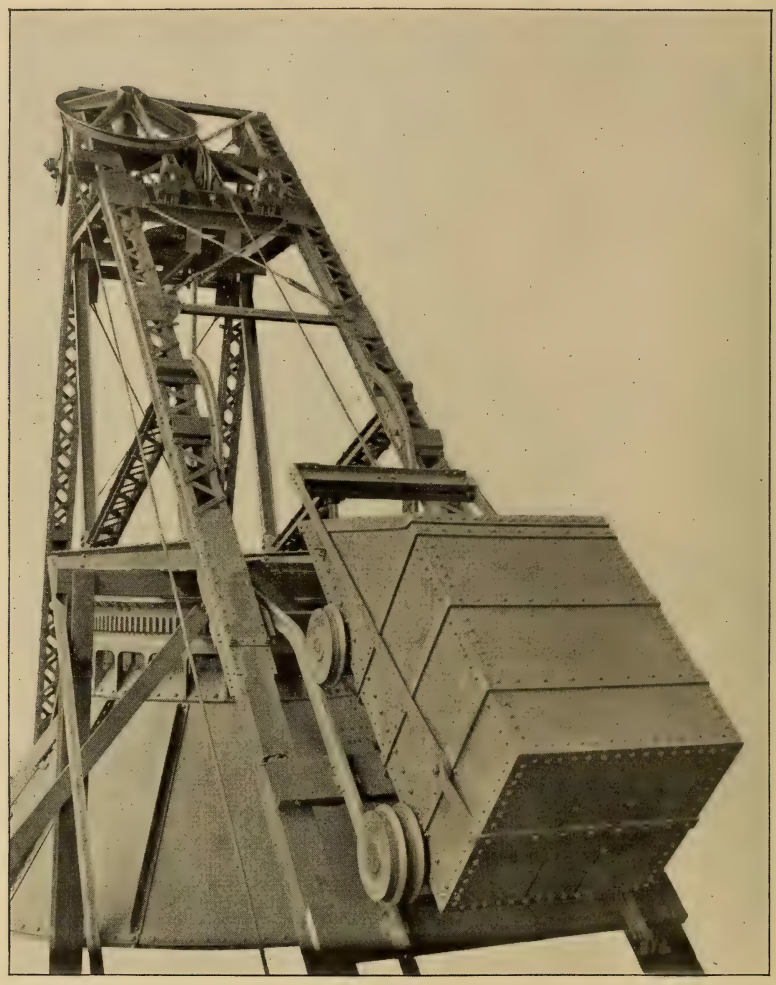


FIG. 15.—ANOTHER MODIFICATION OF THE SKIP-DUMPING METHOD

Fig. 14. In this view only one larry is shown, but the locomotive is designed to haul two, and either one or both can be uncoupled by the operator as he stands upon his platform at the rear. The tracks are so located that the chutes at the bottom of the bin will deliver directly into the larries, and the latter are provided with scales, so that, by drawing successively from different compartments, mixtures of ore in exact proportions can easily be secured.

At the furnace end of each bin the suspended track stringers are extended over the pit into which are lowered the skips which carry the ore, limestone, and coke to the top of the furnace, and the larries having been properly filled, are pushed by the locomotive to a position over a chute guiding to the skip and are there emptied. Between the end of the bin and the skip is a transfer table, operated by a special electric motor, by means of which, if any accident should happen to a locomotive or larry on one side, or if it should become necessary to repair a gate or its operating mechanism, the supplies could all be drawn from one side of the bin and transferred from one track to the other, so as to serve both skips. In a later design, where a wider bin was avail-

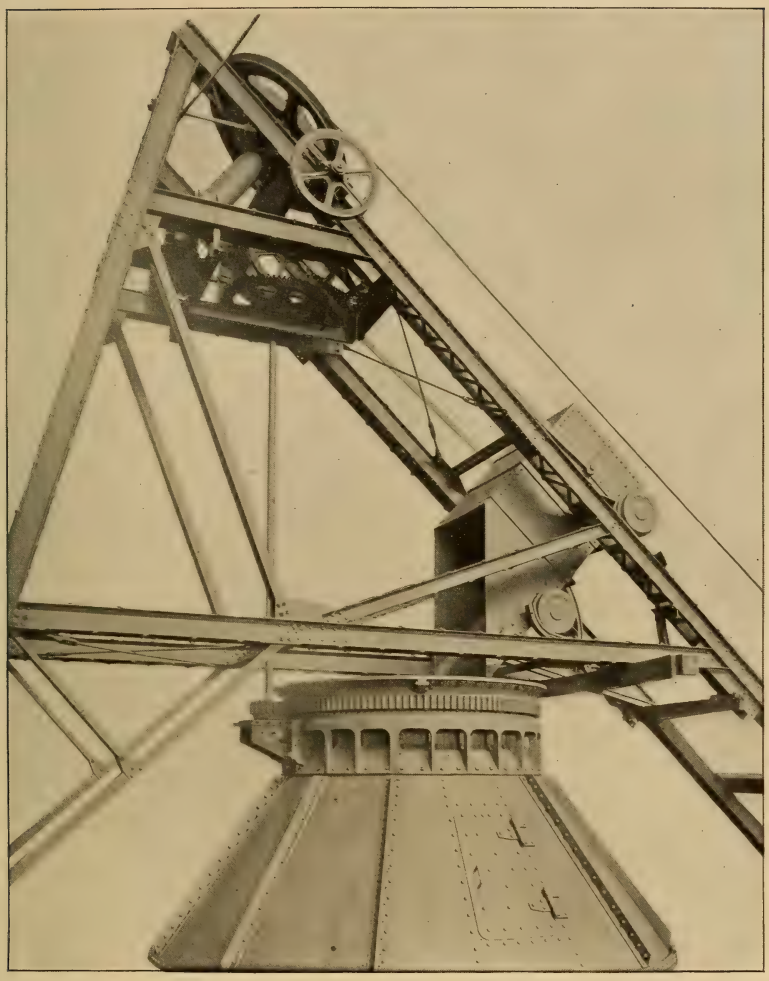


FIG. 16.—THE SKIP IS HERE SHOWN IN DUMPING POSITION

able, a marked improvement has been effected by combining the electric locomotive and larry in one frame with a wider wheel base, making a stiffer and more substantial construction. In this case only one larry was used at a time.

The coke bins, already referred to, are located on either side of the skip pit mentioned above, and are so arranged that the coke is delivered into the same chutes that receive the ore and limestone from the larries and is thus guided into the skips. Two skips are used, running on an inclined double track, from the bottom of the pit in which they receive their loads to the top of the furnace, where they are automatically dumped by means of a peculiar arrangement of tracks and wheels. The front wheels are of ordinary width and follow the main track. The rear wheels are much wider, extending beyond the main track to such an extent that, at a point near the top of the furnace, where a second track is added outside of the main track, these wheels will run on and follow the second track. This track continues in the same inclined plane in which lies that portion of the main track below the point referred to, insuring the continued upward motion of the rear end

of the skip, while at that point the main track leaves this plane and follows a vertical curve, whose centre is below the track, thereby leading the front wheels in towards the centre of the furnace. The rear wheels having continued to rise, the skip is tipped towards the furnace and the contents are dumped into a large hopper. The hoisting mechanism being reversed, the skip descends while its mate rises, the weights of the skips counterbalancing each other, so that the power required is only that necessary to lift the load and overcome the friction.

At the bottom of the hopper into which the materials have been dumped is a cone which distributes its contents with approximate equality, as the ore, limestone, and coke pass through onto a small bell. When two skip loads have thus been deposited on the small bell it is lowered and the distributed mass falls upon the large bell. Again two skip loads are deposited upon the small bell, and it is once more lowered. After the small bell has been raised again to its upper position, so as to form a seal for the gas, the large bell is lowered and the entire mass falls into the furnace, adding a well-distributed layer to those which have preceded it.

The principle involved in the method of dumping the skip described above is illustrated in Fig. 13, which, however, represents a furnace having only a single skip, and the main track, instead of curving in toward the furnace, continues in the same plane, while the outside track follows an upward curve which, raising the rear of the skip, accomplishes the same result. In Figs. 15 and 16 a further modification of this principle is seen, wherein the main track curves in and the second track curves upward. The sharp bend at the end of the main track which arrests the front wheels while the rear wheels continue to rise is clearly shown in Fig. 16.

Figs. 15 and 16 also illustrate another very effective method of distributing the contents of the skip before they are dropped into the furnace. In this method the small bell is dispensed with and the load is dumped into a receptacle which, as the skip descends, is caused to revolve through a small distance by means of the circular rack and a pinion, the latter being connected through a vertical shaft with a system of reducing gearing operated by the large sheave at the top. The receptacle having thus been given a partial revolution, the next skip load is deposited in a new place, and this operation is repeated until, after a thorough distribution has been effected, the entire mass is dropped into the furnace.

This presents in outline the course of the raw materials as they pass from the cars, in which they reach the yard, to the interior of the furnace, all operations, after the cars are left by the locomotive on the dumper floor, being performed by electricity and controlled by a minimum number of human hands, only eighteen men being required to perform all the operations described for the two furnaces.

As mentioned at the beginning, the economy of installing these appliances at considerable expense is found in the reduction of manual labour effected by them; and a careful estimate of the saving in this direction in the plant described above will show that if it is efficiently operated to its maximum capacity a reduction can be secured in the cost of production equal to from forty to fifty cents per ton of pig-iron, which, at the rated capacity of the two furnaces of 1400 tons per day, represents an annual saving of from $200,000 to $250,000.

A RELIC OF TRACTION ENGINE HISTORY

By Frederick A. Scheffler

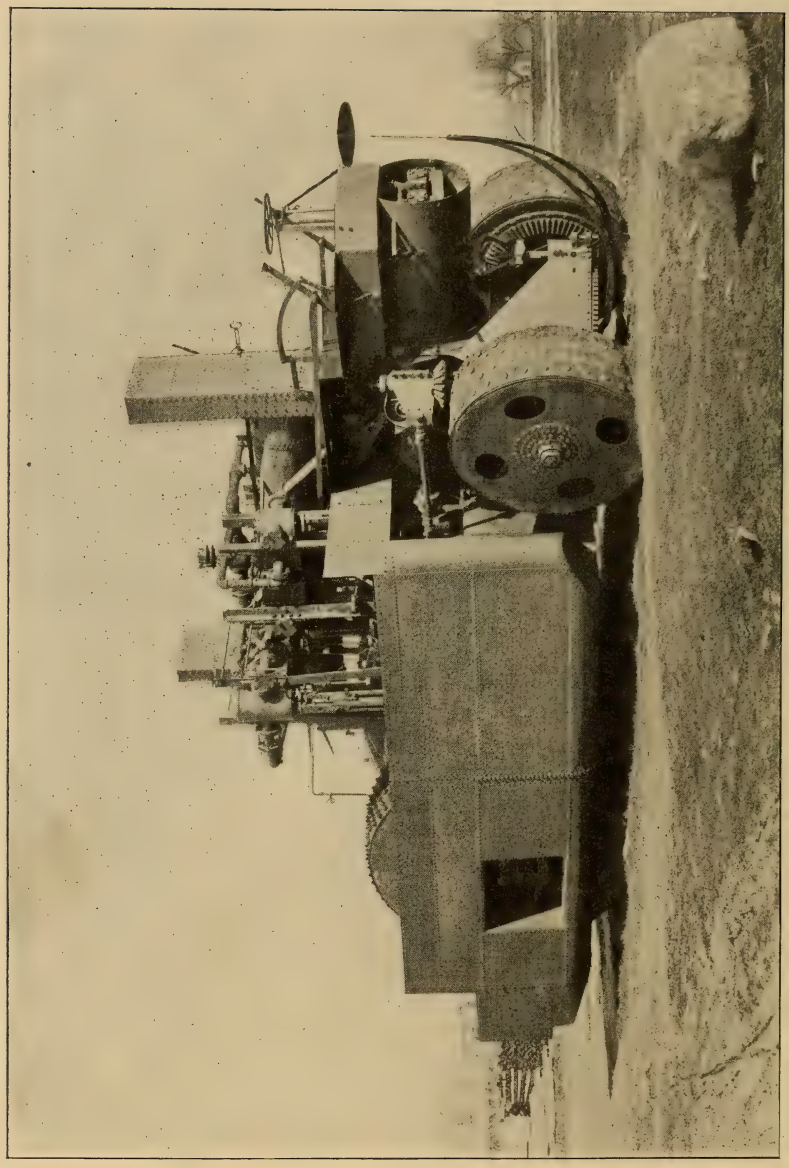
IN the year 1865, two years before the construction of the Union Pacific Railroad, a company calling itself "The Overland Traction Engine Company" was formed in the United States for the purpose of carrying out the designs and plans of one Jesse Fry, who claimed to have invented the only machine capable of making rapid transit a reality between the East and the Far West of the country. Mr. Fry's ideas were original in the extreme, and he had so much faith in them that a small engine was built by him which involved the principles of his purpose and ambition.

Shortly before the completion of this model a wealthy Cuban, who had great faith in the machine as being adapted to the requirements of plantations in Cuba, offered the inventor $400,000 for the whole patent right. But Mr. Fry bluntly refused the offer and said he would not sell his right for $1,000,000. When the model was finished and in actual operation, however, the Cuban gentleman was present. The results on this occasion were enough to convince him that the machine was not what he had expected, and he remarked to the inventor:—"Mr. Fry, I would not give you one dollar for your patent."

Notwithstanding the results of this experiment, Fry organised a company with ample means to carry into execution his scheme of building an engine of the desired dimensions, suitable for the actual fulfillment of his ideas and those for which the company was formed. Everyone who has seen a farm traction engine or a steam roller, such as is used every day by asphalt and other paving companies, will perhaps obtain a general idea of the traction engine conceived by Fry, except that his machine was to be ten times as large and a hundred times more powerful. The projects put forth by the company, and held by them to be the primary objects of the business, were to transport freight, haul immigrant trains or waggons, and carry passengers between the East and as far West as it would be possible for the engine to travel.

The first working engine was constructed at Paterson, N. J. The boiler was not like the type used on locomotives, although the construction of the lower half was somewhat similar. The principal difference was in the upper part and in the connections for the exit of the gases. On top and parallel with the lower part was placed a long steam drum, which was connected to the lower section by means of necks in the shape of frustums of cones having their smallest diameter at the drum. The latter was partially filled with tubes and the whole lower part entirely so. The smoke and other products of combustion could pass directly out through the stack at the front end, as in ordinary locomotives, or they could be deflected, as desired, so that they would pass backwards through the tubes in the drum and thus out at an auxiliary stack at the rear of the boiler. There were three separate water spaces, each supplied with its own feed connections and gauge cocks.

The arrangement proved to be very defective, as the circulation was poor; as a matter of fact, when the steam gauges showed 100 pounds pressure over the crown sheets, the third water space was cold. Instead of the usual locomotive tender, or water and coal tank, which is generally independent in ordinary railway work, the traction locomotive had a large U-shaped tank, between the upright sides of which the boiler was placed. This tank extended



AN AMERICAN PRAIRIE AUTOMOBILE BUILT THIRTY-SEVEN YEARS AGO

the length of the engine, the latter being about 20 feet long.

There were four driving wheels, all independent of one another, similar to the four wheels of an ordinary waggon. The main driving wheels were each 9 feet in diameter, and had a tread or bearing surface 36 inches broad. These wheels were located in the rear of the machine, and the shaft or axle was 9 or 10 inches square with 2-inch holes bored in each end, 4 feet deep, plugged on the outside, and six ½-inch holes drilled on top to lubricate the bearings. The front driving wheels were 6 feet in diameter and 30 inches broad upon their tread.

Each wheel was made of iron boiler plate half an inch thick, backed by 3-inch planking, and the tread, or face, was filled with steel spikes projecting about 2 inches beyond the body of the wheels, making them look very much like the drums of music-boxes. These teeth were intended to insure a sufficient grip of the earth to propel the machine irrespective of the natural adhesion which such an enormous weight would produce upon each wheel. The forward wheels were arranged to be used for steering purposes. The most peculiar thing about the machine was that each wheel had a complete pair of double (two-cylinder) vertical engines, there being, besides, an engine for steering, making altogether nine engines, not including two steam pumps, one of which was used for feeding the boiler, and the other one,—the larger of the two,—for drawing water from a river or creek on the journey for supplying the water tank.

Part of this tank was reserved for a coal bin; but, of course, it was impossible to carry sufficient coal in such a limited space for the intended trip, and coal waggons were, therefore, to be drawn as part of the immigrant train, in which the requisite supply was to be carried.

The driving engines had 10 × 12-inch cylinders, and power from them was transmitted to the rear wheels by a steel link chain, in the construction of which much labour was involved. The front wheels were driven by bevel gearing. The axles were 14 feet long, being more than twice the length of those used on the ordinary type of locomotive. Considering the large wheel tread and the size of the wheels, one can easily imagine the lofty and spreading appearance of the whole outfit.

Before the machine was completed the inventor naturally tried to devise some method of crossing the different rivers on the proposed route which the steam caravan (as the engine and train of waggons might properly be called) would take. At that time there were no boats on the Mississippi and other rivers capable of receiving and transporting a whole train, and the problem of how to cross these streams must have sorely vexed the promoter of the Overland Traction Company. One idea which occurred to Mr. Fry was as original as the rest of the invention, and this was to make the wheels 20 feet in diameter and of sufficient buoyancy to float the entire engine. This suggestion was evidently abandoned as impracticable, for no change was made from the original drawings.

No records can be found of where the journey of the caravan was to begin, but presumably it was to have been from the terminal of the longest railway then in operation in the West. Some fears must have arisen in Mr. Fry's mind that the engine and its train would become an object of attack by Indians. Hence, it seems quite within reason to expect that the engine must carry some method of protection to itself and the proposed train, and one is not astonished to learn that the front of the engine was made of steel plate somewhat in the shape of a fortress, containing cannon in sufficient number to transform the motor into a veritable war engine when necessary.

It is the writer's opinion, however, that the fort was an unnecessary part of the contrivance, for the appearance of this engine invading the territory of the Indians would have been sufficient in itself to cause their sudden departure without the assistance of any cannon.

When the engine was finished it was decided to have a working test made immediately on the street fronting the shop where it was constructed. This street was not paved at that time and

was comparatively level, serving the purpose very well. There was one great objection to it, however, and that was the room between the railway track and sidewalk, which was less than 30 feet; the engine being 20 feet long and 14 feet wide, it is evident that there was not overmuch space for steering should any mishap occur while in transit. The results of this test were most extraordinary.

The writer, who was a stripling at the time, can vividly recall the great commotion among the inhabitants when the long-expected day arrived. As Paterson is well known as a city of large manufacturing interests,—the most important at that time being that of building locomotives,—it is natural that a large part of the community should have turned out to witness the success or failure of a machine which would, without doubt, have furnished new employment for hundreds of men in its manufacture in case of success.

The running of the machine required the services of more men than are now employed in locomotives, there being so many sets of engines to be handled, and whether the results of the experiment were due to a misunderstanding or not cannot now be ascertained. Suffice it to say, that the telegraph poles were knocked down, the street was badly damaged, and several other minor accidents occurred. The steel teeth which were upon the steering wheels for the purpose of enabling the apparatus to be guided easily proved to be the most defective part of the work, for they would grip the earth, as it were, and make it impossible for the small engines used for steering purposes to properly control the movements. At one time the monster narrowly escaped running into a house. After making several more working tests and repeated changes, the idea was abandoned as utterly worthless.

Fortunately no lives were lost by the reckless manner in which the engine was operated during the original and successive trials.

The writer is indebted to Mr. James Wright, of Passaic, N. J., for the photograph reproduced on page 176, which shows clearly the general appearance of the machine and some of the details of its construction.

For plantations an engine of this nature on a small scale could probably have been satisfactorily made, by arranging the mechanism like that of the ordinary traction engine of to-day. Mr. Fry was simply far ahead of his time and had attempted to show his invention upon too grand a scale. The machine, complete, cost $45,000, and when abandoned was sold as scrap. It weighed about 120,000 pounds.

Current Topics

If, as has been maintained, the alcohol motor has no future for motor car work, and is inefficient and far more costly to work than the petrol or oil motor, one would scarcely feel inclined to believe it after looking over what has been accomplished with it in France and in Germany. Indeed, Mr. Frank H. Mason, in his article on heat, light, and power as obtained from alcohol in Germany, printed elsewhere in this issue, furnishes excellent illustrations of the fact that the "spirit" motor, as it is called in Germany, is even now being applied to a wide variety of uses, not the least of which is the driving of all kinds of vehicles. Perhaps, therefore, the alcohol engine is not nearly so bad as it has been painted. Then, too, it must be borne in mind that the matter of economical work depends very largely upon the relative prices of oil and alcohol, and the price of the latter in France, as well as in Germany,—perhaps particularly in Germany,—has been brought down to a very low figure, so that the increased consumption of alcohol in a spirit engine over the quantity of petroleum essence required for the same power may not be worth much consideration. But whatever the disparity of costs may be, alcohol, as claimed by its advocates, has many inherent virtues to recommend it for power purposes. From what experiments have been made, it is learned that the explosion of the alcohol vapour is slower than that of oil vapour and does not partake so much of the nature of a shock, so that less noisy operation is obtained. Coupled with the reduced noise in the exhaust is a sweeter odour, and further, as reported, a lower temperature with a properly designed motor.

Business amounting to considerably over a million dollars a day is the enormous volume standing to the credit of the United States Steel Corporation, as shown by an official statement made early last month at a meeting of the directors by President Charles M. Schwab. The first business year of the Corporation ended on March 31, and the statement in question showed that during that year the Corporation mined 13,326,705 tons of ore, made 9,079,000 tons of coke, and produced 9,035,000 tons of steel ingots. In the same period the entire United States produced, including, of course, the output of the United States Steel Corporation, 13,369,000 tons of steel; hence the output of the Corporation amounted to a little

less than three-quarters of the country's entire output. Great Britain produced in the same time 4,850,000 tons of steel, the Steel Corporation's output being twice as much as Great Britain's. Germany's output in the same time was 6,394,000 tons, and the output of France 1,465,000 tons. The total business of the Steel Corporation for the year, that is, the selling value of the company's products shipped, amounted to the enormous sum of $459,090,000. The amount paid out in railroad freights during the year, outside of the Corporation's own railroads, was $54,147,000. The Corporation paid in wages $112,829,000, and the average number of employees in service during the year was 158,263.

THE recurring destruction of telegraph and telephone overhead lines, and, to a less extent, of electric light and power circuits, due to the severe winter storms, periodically directs attention to the question of placing all electric wires underground. In cities this is, as a rule, quite feasible, and in many of them it is already an accomplished fact. The first cost has hitherto always been the deterrent to placing the wires underground in cities, but it is quite well established that the increased cost of maintaining electric wires underground is more than offset by immunity from sleet and wind storms, as well as the freedom from other incidental damage to which overhead wires and the poles supporting them are exposed in cities, which necessitates an entire renewal of the overhead system about every ten years. So far as the actual operation of electric light and power circuits is concerned, there is no electrical objection to placing the wires underground, but it is different in the case of telegraph and telephone circuits, in which the retarding and interfering influence of static induction comes into play. In the case of the telephone the matter of induction or cross-talk between wires of different circuits is avoided by the use of metallic circuits arranged in cables, in which the wires are "twisted and paired"; but in telegraph practice only one wire is allowed to each circuit, the ground or earth being used as a "return," and, hence, the effects of static induction are much more strongly felt when the circuits are placed close together, as in cables, than is the case when the wires are widely separated on poles. Still, these effects are not so harmful as to interrupt service on the comparatively short distances that the wires run in cables in cities, albeit a slight reduction in the speed of signaling is noticeable, and the greater freedom from physical interruptions that the wires enjoy when underground measurably compensates for the slight impairment of the service otherwise.

IT is, however, not now so much a question of placing the telegraph and telephone wires underground in cities that is mooted, as whether it is feasible to place them underground in cables between cities everywhere, to avoid the disastrous delays to business and loss of property that have taken place in the past, and that must continue to occur so long as the wires are exposed to the ravages of the elements. It may, however, be said at once that the question is only raised to be dismissed, for the extent of territory to be thus covered and the ramifications of the telegraph and the long-distance telephone are such that the cost of such an undertaking would be ruinous. But apart from cost, the prospective impairment of the service along the lines indicated would doubtless in itself be a sufficient reason to induce the telegraph and telephone directors to continue to bear the ills they have than fly to others that are pretty clearly in view.

WHILE it may sound strange, it is nevertheless true, that inquiries for automobiles are being made in Syria. Only one specimen, an inferior second-hand French machine, so says United States Consul G. Bie Ravndal, at Beirut, has been seen there; but it is thought that

in Syria and Palestine, with their lack of railways and street cars and with their rapidly developing carriage-road systems, automobiles would do well. A new road is now being built between Sidon and Beirut, and will soon replace the ancient bridle path. While this road will be level, others throughout the region are steep and make numerous sharp turns. Vehicles in use, therefore, must be strong and durable. Horses suffer greatly from the heat, and this difficulty would not apply to a machine. In Beirut alone 500 carriages are running, and hundreds more are in use in the Lebanon and in Palestine. The country is poor, and, except possibly for the accommodation of tourists, there would not at present be much demand for automobiles outside of Beirut; but this demand, as all indications show, is likely to grow rapidly. The tourist traffic has more than doubled in Syria during the last ten years. At present about 750 foreign tourists pass through Beirut annually, most of them proceeding to Baalbek and Damascus. Twice this number go through Palestine. Galilee is also growing in favour among them. The figures given do not include pilgrims, thousands of whom seek the holy places, nor the special excursions which lately have come into vogue.

THE question of the employment of hard-drawn copper for overhead line wire was one concerning which conflicting views were held fifteen or sixteen years ago, when the extensive use of this metal began in the telegraph and telephone service. At that time, and at intervals since then, the advocates of silicon bronze and phosphor bronze wire have urged the employment of those metals for overhead wires, especially for telegraph and telephone purposes, chiefly on account of the greater tensile strength of such wires as compared with hard-drawn copper wire. Indeed, several hundred miles of such wire were experimented with in 1882 and 1883 by the British Post Office telegraph department, presumably in the belief that hard-drawn copper wire was not suitable. The fact, however, that hard-drawn copper wire possesses 98 per cent. of the conductivity of pure copper, has ample tensile strength to support itself on the poles, and is sufficiently ductile to meet all the requirements of practice, has hitherto seemed to telephone and telegraph engineers in the United States a valid reason for employing this metal in preference to silicon or phosphor bronze wire, with but 85 per cent., and less, of the conductivity of pure copper, even admitting the greater tensile strength and ductility of the latter wires.

IT is fairly well known that the tensile strength of hard-drawn copper wire lies in the thin, hard, polished crust or shell, not much exceeding 0.001 inch in thickness, which is formed over the wire by the process of drawing through the die, as is evidenced by the fact that the slightest cut made around the shell with a sharp instrument will at once greatly lower its breaking strain and permit it to be broken with one bending. Inside of this shell the wire appears to be comparatively soft. One of the advocates of silicon bronze wire, referring to this feature of hard-drawn copper wire, says: —"Under the action of heat and cold in service,—a variation of 150° F. between winter and summer being assumed,—the molecules of the compressed copper on the outside of the wire have a chance to readjust themselves in their uncomfortable and crowded position. As a result of this the internal strains of the wire come into play, the wire is gradually restored to a homogeneous condition, and the original tensile strength, under which the wires were taut and things of beauty to look at, has been replaced by the tensile strength of wire in a comparatively soft state." If this hypothesis were true, it should follow that the hard-drawn copper wires erected fifteen and sixteen years ago should now have elongated, as annealed copper was wont to do when it was first employed in telegraphy over fifty years since, until it touched the

ground. It is, however, well known that nothing of this kind has happened. It is true that many miles of hard-drawn copper wire have been taken down from the poles and sold as scrap to make room for hard-drawn copper wires of larger sizes. But this scrap copper brought to its owners more money than it originally cost, owing to the rise in the price of copper. It may further be noted that hard-drawn copper telegraph and telephone wires show no signs of corrosion after fifteen years of service. Iron telegraph wire, on the other hand, after ten or fifteen years of service is, in the majority of cases, little more than, as has been aptly said, a streak of rust. Of course, for long spans, as over rivers or ravines, the high tensile strength of silicon or phosphor bronze wire would render it superior to the hard-drawn copper article. It may be noted in connection with this subject that the almost total disuse of iron wire for overhead telegraph purposes, predicted by many upon the advent of hard-drawn copper wire, has not followed, and large quantities of iron wire are still being employed for this purpose, as an instance of which it may be stated that one of the largest iron wire works was recently 27,000 miles behind orders for galvanised iron telegraph wire, notwithstanding that the works had been going night and day for over two years. The high price of copper during the past few years has doubtless contributed very measurably to this continued use of iron wire.

THE filling up of water jackets of gas engines with deposits of lime and mud from impure circulating water, much after the manner of steam boiler incrustation from similar causes, is something that might reasonably be expected to happen, and it is very likely that some of the puzzling troubles now and then encountered in working gas engines could be explained by a little jacket examination. The blocking of the water passages would mean insufficient cooling water, or even none at all, consequent overheating of the cylinder, defective lubrication, and other ills. Several instances are on record of such scaling-up of cylinder jackets, and in these cases suitable safeguards were adopted against repetition of the trouble.

HEAVY ordnance is not quoted in the steel market, and it has no established price in the hardware trade. The United States Arsenal at Watervliet, N. Y., however, reports the cost of the goods which it manufactures, some of its particularly striking figures being the following:—12-inch breech-loading rifle, $39,248; 10-inch breech-loading rifle, $23,424; 8-inch breech-loading rifle, $12,269; 6-inch rapid-fire gun, $7,527.

THE United States Weather Bureau has published the results of statistics which it has gathered during the past decade relative to the deaths by lightning in the United States, and while the figures are of doubtful practical utility, they are certainly of considerable interest. The old question used to be how to protect buildings against lightning, —lightning-rods or none, solid rods or hollow rods, and on the latter point men like Faraday and Sir William Snow Harris took opposite sides and waxed wroth, each telling the other he knew nothing about the subject. To-day little or no attention is given to this matter, and it is generally realised that as regards where lightning will strike we must all take our chances, which, according to the statistics referred to, are about 1 in 100,000 of being struck. The old idea that lightning will never strike twice in the same place has been pretty well exploded by the actual facts, and there is reason to assume that if lightning strikes a given point once it may be expected to strike there again, rather than at some other contiguous place. The theory of lightning is now fairly well established. It is supposed to be due to the rapid condensation of the minute drops of moisture in the air, each of which, under certain conditions, con-

tains a small electric charge. As these minute drops coalesce, the electric potential is increased, due to the fact that the total superficial area of the coalesced drops is less than twice that when they existed singly, and, as the electric capacity is proportional to this area, the electric charge of the two drops is now confined within an area of less capacity than before, with the result that the electric pressure is increased. In this way, long before the drops have attained a size to be precipitated as rain, an electromotive force amounting to millions of volts is developed. While there is no certain immunity from lightning when it prevails, attention is called to the great desirability of persevering in efforts to resuscitate those who have been rendered insensible by lightning strokes, as recoveries have repeatedly been made of persons supposed to be dead, after more than an hour's efforts. The statistics also show that there is no immunity from lightning in a feather bed, in a house, or in a closet, and that knives and the like do not attract lightning. For those who are inherently dreadful of lightning the only comforting suggestion that can be offered is to remember that if one lives to see the flash he is safe for that time!

ALEXANDER E. BROWN

Vice-President and General Manager of the Brown Hoisting Machinery Company

A BIOGRAPHICAL SKETCH

IN the comparatively short period of twenty years the Brown Hoisting Machinery Company, of Cleveland, Ohio, has developed into the largest establishment of its kind in the world, with from 1200 to 1400 men in its works, with travelling representatives all over the world, and with its various products likewise distributed in many lands. No better introduction than this could be given to the ruling spirit of this enterprise, Mr. Alexander E. Brown, whose portrait appears on the opening page of this issue.

Mr. Brown was born at Cleveland in 1852, and was educated at the public schools of that city, the Central High School and the Polytechnic Institute, of Brooklyn, N. Y., where he took a special course in civil and mechanical engineering in 1872. Then the lad went with Dr. F. V. Hayden on the original United States Geological Survey to Yellowstone Park, which occupied him for one year. Afterward he became chief engineer of the Massillon Bridge Company, remaining with that company until 1874. Then he established himself as a general mechanical and civil engineer in the city of Cleveland. Mr. Brown made a specialty of iron, steel, and blast-furnace work, also paying attention to mining and railroad engineering. He designed and put into use a system for malleable iron works for charging and handling material to and from the annealing ovens, which is now generally in use, and is controlled by the National Malleable Casting Company, who bought the patents.

From 1878 to 1879 Mr. Brown was engaged by the Brush Electric Company as mechanical engineer and chief assistant to Charles F. Brush, the inventor of the Brush lighting system. In 1880 he took up the question of the handling of materials and the betterment of terminal facilities at the Lake ports, more particularly in regard to iron ore and coal, and since that time has been continuously engaged in the manufacture of machinery for this purpose. To what extent he has succeeded is proved by the present existence of the Brown

Hoisting Machinery Company, which is successor of the Brown Hoisting and Conveying Machine Company, organised by Mr. Brown in 1880.

The first plant was erected on the Erie docks at Cleveland, and the system has practically revolutionised the entire Lake trade, increasing the output and expediting and cheapening loading and unloading of vessels to such an extent that to-day the vessel freights on the Lakes are about one-quarter of the lowest freight for similar distances and cargoes anywhere else in the world. The increased and better terminal facilities have also produced an entire change in the type, kind, and size of the Lake vessels. In 1880 a vessel of from 1000 to 1200 tons capacity was a rarity and considered very large, while to-day a vessel of from 7000 to 8500 tons is the size commonly built, and the largest boats of 1880 can no longer engage in the trade profitably.

The system, however, is not only in use for the loading and unloading of vessels, but is operated in the largest iron and steel works and iron mines, a very good example being the subject of one of the articles in this issue, dealing with the ore-handling plant at the Carrie furnaces of the Carnegie Steel Company, at Pittsburgh. Recognising the results obtained in this country by the various classes of machinery designed and built by the Brown Hoisting Machinery Company, foreign manufacturers of steel and iron, mine owners and shippers have installed and are rapidly installing the system in their various plants, in order to meet American competition.

There is scarcely a country in the world without some specimen of the Brown Hoisting Machinery Company's manufacture. Mr. Brown has taken out many hundreds of foreign and American patents to protect his inventions during the last twenty years, covering every phase of hoisting, conveying and handling of material in large manufacturing plants.

In December, 1900, a fire destroyed the works of the Brown Company, and an entirely new plant was laid down, with double the capacity, on the same area as the old plant, and supplied with every modern appliance, the area covered being about ten acres.

Mr. Brown is the vice-president and general manager of this large corporation. He is also a member of the American Society of Mechanical Engineers, the American Institute of Mining Engineers, the Society of Civil Engineers of Cleveland; the Society of Electrical Engineers of Cleveland; the Union and Country clubs, of Cleveland; and the Engineers' Club of New York.

CASSIER'S MAGAZINE

MINING AND METALLURGICAL NUMBER

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GOLD MINING IN THE TRANSVAAL, SOUTH AFRICA

By John Hays Hammond

Mr. Hammond's international reputation as an authority on South African gold mining at once commands attention for any contribution by him on that subject, and is, in itself, a sufficient reason for the partial reproduction in the following pages of a paper presented by him last year before the American Institute of Mining Engineers, but later carefully revised by the author and subsequently re-arranged specially for use here. It admirably covers some of the more prominent features of the subject in hand, and is accompanied by some new and hitherto unpublished illustrations. The author, moreover, acknowledges the aid received, as to many statistical points, from the criticisms of Mr. Thomas H. Leggett, the well-known mining engineer on the Rand.—THE EDITOR.

SOUTH AFRICAN "BOYS" WITH A RAND DRILL

THE Transvaal comprises about 120,000 square miles. Besides the famous Witwatersrand, which will here be described in detail, there are two quartz-mining districts of some importance, viz., Lydenburg and De Kaap. The Lydenburg district first attracted attention in 1876, when the alluvial deposits of that section began to be exploited. At a later period vein-mining was started. At the present time several companies are operating in that district in a small way. The product in 1898 of four companies, running 135 stamps, was 154,560 tons of ore, yielding 108,884 ounces of gold (an average of 1.42 ounce per ton), valued at £392,378.

The De Kaap gold fields were discovered in 1884. In 1898 seven companies, running 180 stamps, produced 89,760 ounces of gold, valued at £314,792.

MINING TITLES IN THE TRANSVAAL

Notwithstanding the change in the political status of the Transvaal likely to follow the present war, it may be confidently assumed that the main features of the mining law of the South African Republic will be retained, though certain oppressive features of ground taxation, monopolies, etc., bearing with special weight on the mining industry, may be abolished. These, indeed, form no part of the mining law proper,—that is, the law regulating mining titles. It is to be expected,

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A VIEW OF WITWATERSRAND. IN THE FOREGROUND CAN BE SEEN PART OF THE VILLAGE, THE MAIN REEF COMPANY'S CYANIDE WORKS, EXTRACTOR HOUSE, AND TAILINGS DUMPS. FURTHER BACK IS JEPPESTOWN,—A SUBURB OF JOHANNESBURG. ON THE HILLS AT THE LEFT ARE THE JOHANNESBURG RESERVOIRS

ORE BINS OF THE LANGLAAGTE DEEP, LTD.

both in the nature of the case and in view of the declarations already made by British statesmen, that the "ancient laws and customs" of the Transvaal will be retained under British rule as far as possible. At all events, the principles of the British common law and the immemorial precedents of British practice will, undoubtedly, require the determination of present rights according to the status at the time of their inception. The mine operators of the Transvaal whose titles were acquired from the Republic will, therefore, be secured in the position thus defined; and hence it is not inappropriate in this place to state the Transvaal mining law as it existed prior to the present war.

According to that law, the right of mining for and disposing of all precious metals and precious stones belongs to the State; but the State president, with the advice and consent of the executive council, may, by proclamation, throw open government ground as a public diggings, upon which mining claims can be "pegged off" (*i. e.*, located) as specified by law. An owner of a farm may, upon application to the government, have the farm likewise proclaimed. Before the proclamation of a private farm the owner has the right of allotting to any person or persons he may specify a certain number of claims, called *Vergunning* claims, the number depending upon the size of the farm, but not exceeding sixty as a maximum.

The owner has the further right to reserve for himself one-tenth of the ground, which is called a *Mynpacht.* This portion is held by the owner as a lessee, under what is called a *Mynpacht Brief*, for a term of not less than five years, nor more than twenty years, with the privilege of renewal. The rental on *Mynpacht* is 10s. per *Morgen* (2.11 acres).

He may also retain a certain area for residential and farming purposes, called a "*Werf*" or homestead. Finally, the owner of a proclaimed farm is entitled to one-half of all licenses paid to the government. A reef-claim (lode-claim) is 100 Cape feet (103.3 English feet)

A ROPE HAULAGE PLANT FOR CARRYING ORE AT THE CROWN DEEP GOLD MINES. INSTALLED BY ARTHUR KOPPEL, LONDON, BERLIN, AND NEW YORK

on the strike of the reef by 400 Cape feet (413 English feet) in the direction of the dip,—about 1.5 acres.

TABLE I.—SOUTH AFRICAN LAND-MEASURES

1 Cape ft.	= 1 033 English ft.
1 Cape sq. ft.	= 1.067 English sq. ft.
1 Claim	= 150 by 400 Cape ft. = 60,000 Cape sq. ft. or 64,025 English sq. ft. = 1.47 English acres.
1 Morgen	= 92,196 English sq. ft. = 2.1165 English acres of 43,560 sq. ft.

Prospecting is not allowed on private ground without permission of the owner, but public ground is open to prospectors, though claims may not be pegged out until after proclamation of the ground in question as above described. For a prospecting license on proclaimed private ground there is a charge of 5s. per month per claim, half of which goes to the owner and the rest to the government On government ground the similar charge is 2s 6d. per month, which goes to the government.

When, in the judgment of the mining commissioner, the results of the exploration justify the step, he may convert the prospecting licenses into a digger's license, after which a charge of 20s. per claim per month is made, provided ore from the property is being crushed. If, however, no ore is being extracted and crushed from the claim, the charge for the digger's license is 15s. per month. In 1896 the receipts from prospecting licenses amounted to £620,000; from diggers' licenses, £61,000, and from machine-stand licenses, £59,000.

GENERAL FEATURES OF THE WITWATERSRAND

The mining district derives its name from the *Witwatersrand*, or "white-waters range," of hills immediately north of Johannesburg. These hills rise from 400 to 600 feet above the general level of the surrounding country, have a general east and west trend, and constitute the watershed of this part of South Africa, their northern slope draining into the Limpopo River and thence into the Indian Ocean, and their southern slope into the Orange River and thence into the Atlantic. This ridge can be traced about forty miles, and

consists of quartzites and interstratified schists.

The gold field lies on the high plateau of the southern Transvaal. It is destitute of trees other than a sparse growth of shrubs, and in appearance suggests herding and agriculture rather than mining. It is from 4200 to 6000 feet above sea-level, to which fact it owes its temperature and mild, salubrious climate, in spite of its semi-tropical latitude. The low-lying coastal lands contiguous to the Transvaal are, on the other hand, malarial and unhealthy.

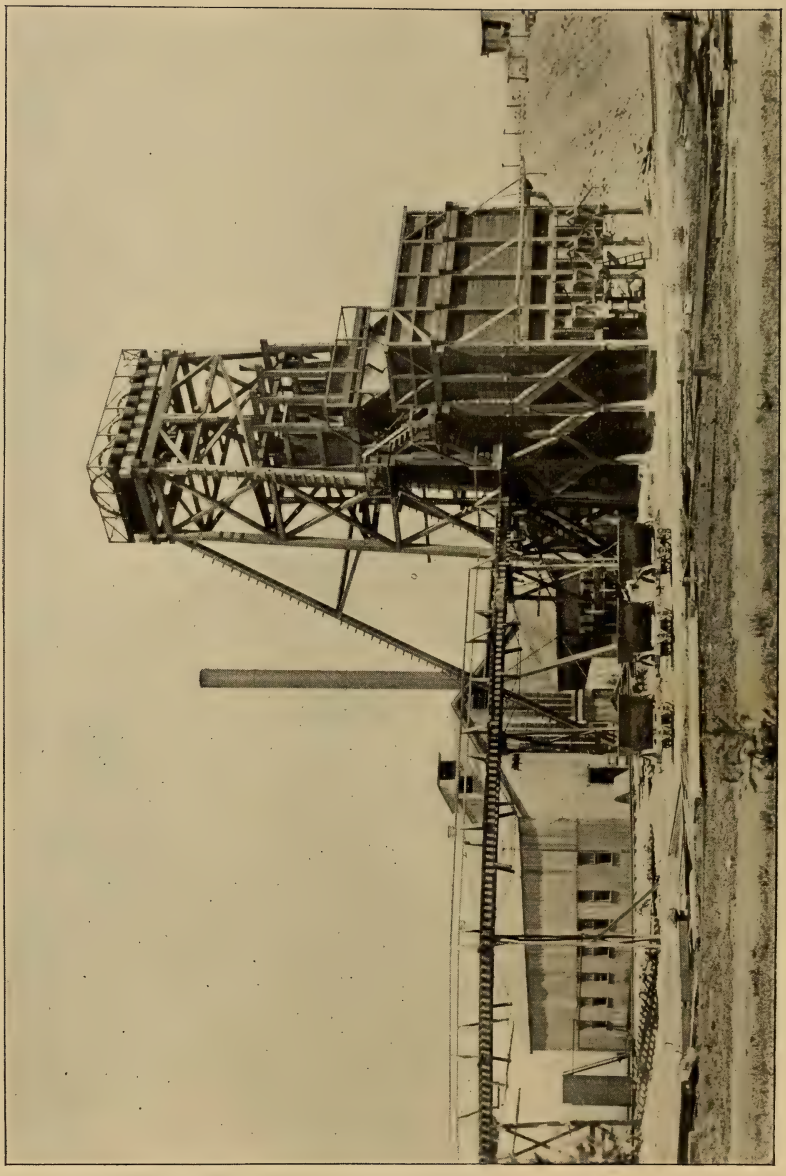
The soil of the country is, in most localities, fertile; but irrigation is generally necessary; and this, owing to the lack of facilities for storing water, is not feasible at the present time. The Transvaal has a rainy season of four or five months, the heavy rains commencing usually with November or December and continuing until March or April. This is what is known as the summer or warm season. The thermometer rarely reaches 95 degrees in the shade, and the heat is "dry." During the remaining "winter" months (April to September) rain is very exceptional, and there is no extreme cold. Snow is a rare occurrence in the Witwatersrand district. While the climate is remarkably salubrious and invigorating, the district has had in the past a high rate of mortality, by reason of the lack of proper sanitation. Undoubtedly this will be greatly minimised under better government.

The town of Johannesburg lies upon the southern slope, about midway between the east and west extremities of the "banket" basin, immediately to the north of what is known as the central section of the Rand. This is by far the most important mining section of the gold field. The Witwatersrand district, in a comprehensive sense, embraces also the outlying districts of Heidelberg and Klerksdorp. Johannesburg is reached by three railway lines, from the ports of Cape Town, Delagoa Bay, and Durban, the distances by rail being 1013, 377 and 483 miles, respectively. At the outbreak of the war the town contained about 75,000 whites, almost all Uitlanders (foreigners), the Boer residences being usually rural. It contained also about 25,000 blacks. The city is well laid out, and has many fine office buildings and residences. The handsomest of the latter are situated a mile or two from the centre of the business portion of the town, along the slopes of the Witwatersrand.

HISTORICAL AND COMMERCIAL NOTES

Mining in the Transvaal was prohibited until 1868, at which time the government, being in dire financial straits, threw open the gold fields to exploration and exploitation by all comers, and even went so far as to offer a bonus for the discovery of profitable mines in the country. As a result, prospecting in the early seventies led to the discovery of quartz veins and the inauguration of mining in several parts of the northern Transvaal. In 1885 the conglomerate or "banket" beds of the Witwaters-

NATIVES BOUND FOR THE GOLD FIELDS



THE USUAL FORM OF HEADGEAR AND ENGINE HOUSE

rand were discovered. In that year a small stamp battery was erected to crush the material of a quartz vein a few miles west of Johannesburg, and a crushing of conglomerate was subsequently made in this battery. But it was not until April, 1887, that a battery of three stamps was erected to treat the ore of the Witwatersrand "banket." This was followed by the erection of other batteries, and the output of gold for that year was 23,000 ounces. The product increased by leaps and bounds, as is shown by the table of production given on a later page.

At the outbreak of the war the total capitalisation of the gold mines of the Witwatersrand was over £70,000,000 at par, and at market prices about £147,000,000. A large part of these amounts represents worthless properties which have been "floated" during "boom" times; yet, notwithstanding this excessive capitalisation, the mines yielded about 7 per cent. on the total capitalisation at par, and about 3.5 per cent. on market prices. Eliminating properties notoriously without value, and also the capitalisation of certain "deep level" properties which have not, as yet, reached a producing stage, we may pronounce the returns from *bona fide* investment and competent management to have been exceedingly satisfactory.

In 1898 seventy-seven companies operating stamp batteries produced 4,295,609 crude ounces of gold of the value of £15,141,376, and distributed in dividends for that year £4,847,505, or about 15.6 per cent. on their nominal capital of £34,000,000. The market capitalisation of the same companies, however, was £82,555,000; and the dividends returned on this capitalisation were about 5.9 per cent.

The majority of the "outcrop companies,"—indeed, nearly all of those situated in the central section (extending from the Langlaagte Estate to Knights, on the Witwatersrand),—are free of indebtedness, and will not require further capital, unless for future increase of plant, especially for enlarging their milling capacity. Any additional capital required for such purposes could be provided either from the profits already earned, or by the issue of debentures, to be ultimately likewise redeemed from profits.

For the "deep-level" properties, on the other hand, and especially for those covering the deeper levels, *i. e.*, those situated on the second and third lines of claims parallel to the outcrop, a large amount of money must be expended before the mines can become productive. Instead of increasing the capital stock for this purpose, it is generally the practice of the Rand companies to raise the money by the issue of debentures. There has been no difficulty in obtaining working capital by these means, often to the extent of £400,000 or £500,000. About £5,000,000 of such debentures have been issued.

Houses of high standing have been able to raise such loans of working capital upon debentures bearing interest at 5 to 6 per cent. per annum, giving as an inducement to the purchaser the right to exchange the debentures for fully paid-up shares, at a certain price, within a given period from the date of issue, during which period the shares are likely to command a good premium.

Nearly all the Rand companies are controlled by large financial concerns, such as Wernher, Beit & Co., who control the Rand Mines group and some other properties; the Cons. Gold Fields Company, which controls the Simmer and Jack (one of the largest mines on the Rand), the Robinson Deep, the Nigel Deep, and some of the first, as well as many of the second, row of "deep-levels"; the Messrs. Farrar, who control the East Rand Proprietary and its subsidiaries, the Angelo, Dreifontein, New Comet, etc.; Barnato Brothers, who control the Primrose, Glencairn, Ginsberg, Roodepoort, etc.; and A. Goerz & Co., who control the Goldenhuis Estate, the May Cons., the Lancaster and the Geduld Princess Estate, etc.; Mr. Neumann and associates, controlling the Cons. Main Reef, New Modderfontein, Treasury and Wolhuter; Messrs. Alba, controlling the Aurora West, Meyer and

Charlton, Van Ryn, etc.; and Mr. Robinson, who controls the Robinson group, comprising the Langlaagte and Randfontein Estates and their several subsidiaries. These parties have the entire financial and technical direction of the companies, in which they possess a major voting interest. All the important companies are listed on the stock exchanges of Johannesburg and London.

The financial administration of the Witwatersrand mines is, as a rule, able and honest. The Transvaal law requires a monthly statement of the amount of ore crushed, gold produced, etc. Such reports are published monthly by the companies, in great detail.

As a rule, the Johannesburg local directors and mine managers are exceptionally trustworthy, and full reliance can be had on the accuracy of their reports. Sometimes, however, attempts are made, for market purposes, to underestimate the working costs, by charging to capital expenditure money which should strictly be reckoned as working expenses. In this way fictitious profits may be shown; but the practice is not usual, and latterly has been seldom adopted.

TABLE II.—GOLD-PRODUCTION OF THE DISTRICT

	Ounces	Value £	Dividends £
1887	23,125	81,042	12,510
1888	208,122	734,477	67,653
1889	369,557	1,300,514	407,599
Unrecorded	42,000		
1890	494,817	1,735,491	146,927
1891	729,268	2,556,328	394,717
1892	1,210,869	4,297,610	811,864
1893	1,478,477	5,187,206	1,100,203
1894	2,024,164	6,963,100	1,540,394
1895	2,277,640	7,840,779	2,198,943
1896	2,280,892	7,864,341	1,638,881
1897	3,034,678	10,583,616	2,759,505
1898	4,295,609	15,141,376	4,847,505
	18,469,218	64,285,880	15,926,701
Jan. to Oct., 1899, Chamber of Mines	3,946,546	---	---
November, 1899, Government returns	61,780	14,273,000 (ap.)	2,933,251
	22,477,544	78,558,880	18,859,952

In the formation of a new company the owner or owners of the mining claims (and often the financial promoting syndicates) usually receive a certain number of vendors' shares of the company to be formed by an amalgamation of claims. Moreover, a certain number of shares are sold (usually at par) for working capital; and a certain number of shares are retained as a treasury reserve, which frequently are sold, some time afterwards, at a considerable advance. The majority of the companies have greatly increased their capital since their formation; but, notwithstanding this fact, their new shares are in many cases several hundred per cent. above par. The total dividends paid up to 1899 by the Witwatersrand gold mining companies amount to £18,859,952. There is little doubt that within the next few years this sum will be very considerably increased. Dividends increased from £811,864 in 1892 to £4,847,505 in 1898. In this calculation, to arrive at the working costs, the dividends are

DIVIDENDS AND EXPENSES PER TON OF ORE MILLED

Year	Ore Milled Tons	Value Per Ton of Ore s.	d.	Dividends Per Ton s.	d.	Expenses Per Ton s.	d.
1892	1,979,354	43	5	8	2	35	3
1893	2,203,704	47	0	9	11	37	1
1894	2,830,885	45	7	10	10	34	9
1895	3,456,575	45	4	12	8	32	8
1896	4,011,697	39	2	8	2	31	0
1897	5,325,355	39	9	10	4	29	5
1898	7,331,446	41	3	13	2	28	1
1899	6,639,355	41	3	8	11	32	4

deducted from the total yield of all porducing mines, and the remainder is considered to be the cost of production. Out of the seventy-nine producing gold mines, only thirty-six actually paid dividends. The high cost per ton figured out on the above basis for 1899 is due to the fact that a large amount of the profits actually earned and available for dividends were not distributed, being kept in hand to provide for extraordinary expenses expected by reason of the impending war.

During 1898 there were crushed by 4765 stamps 7,331,446 tons of ore. The number of white employees was 9476, receiving an average monthly wage of £26. The native labourers numbered 88,627, receiving £2 9s. 9d. each per month, besides food and lodging. The number of stamps will be gradually increased by addition to the batteries now in use and by the erection of new batteries upon the outcrop, and, principally, upon the "deep-level" properties.

From January to October, 1899, there were milled 6,639,355 tons. From

January to August of that year the average number of stamps running was 5762, the highest number at any one time being 6165. The yield of ore treated showed no change, the returns having been, per ton, from the mills, 6.41; from tailings, 4.07; and from slimes, 2.01 dwts. of fine gold per ton. Including the returns from concentrates and by-products, the total yield per ton of ore crushed was 10.10 dwts. of the value of 41s. 1.3d. pence, the weight being fractionally higher, but the value exactly the same as the year before.

The average proportion of waste sorted out was 19.71 per cent. In other words, only about one-fifth of the ore raised from the mines was rejected at the surface.

When the companies ceased working in October, 1899, by reason of the declaration of war, the late Transvaal Government continued mining operations on its own account, upon some of the richest mines, up to May, 1900. These operations gave a yield semi-officially reported at about 490,000 ounces of fine gold, worth, say, £2,000,000. Particulars as to the tonnage crushed, working expenses and profits, are not obtainable. In May, 1901, crushing operations were resumed on a small scale by the companies themselves, 150 stamps being run at three mines. This number has steadily increased until, in December, 1901, there were 653 stamps running, representing twelve mines. During the eight months ending December, 1901, 412,006 tons of ore were milled, producing 238,995 ounces of fine gold, valued at £1,014,687, or 49s. 3d. per ton, and dividends amounting to £415,812 were paid, equal to 20s. 2d. per ton of ore milled.

In this connection, the mines may be conveniently classed in three groups:—those in the outside districts of Heidelberg and Klerksdorp; those upon the main reef series, extending easterly and westerly about twenty miles from Johannesburg as a centre; and the deep level mines of the first, second and third rows, and still deeper "deeps."

Heidelberg and Klerksdorp.—The Nigel, Rand-Nigel, and Nigel Deep are at present the only producing mines in the Heidelberg district; but several other properties are being opened for future exploitation. In 1898 this district produced 34,431 ounces fine gold, worth £141,736.

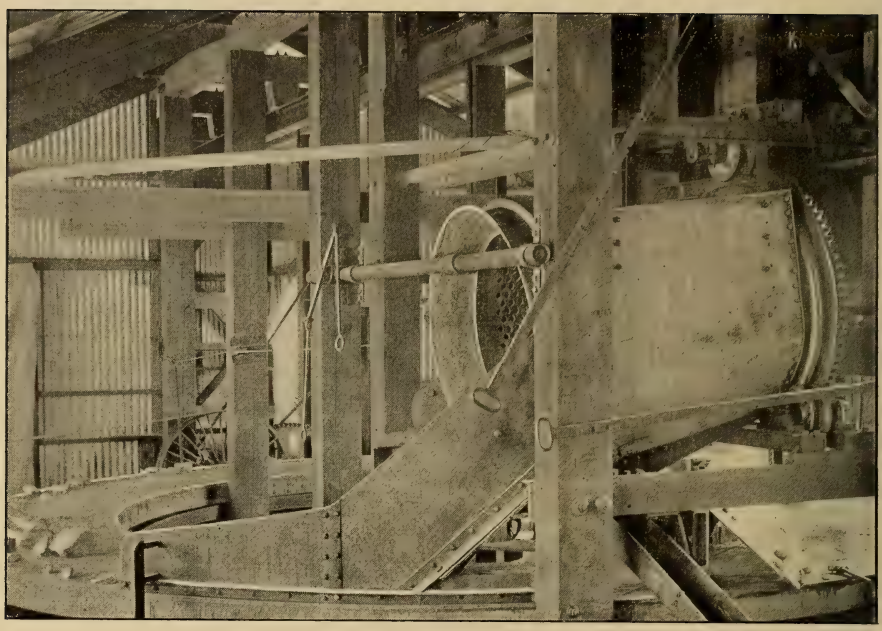
So far as developed, the important mining ground in the Heidelberg district is that of the Nigel, the Nigel Deep, and the Central Nigel Deep, constituting the first and second rows of deep levels below the Nigel, which is the outcrop mine. These mines are situated about thirty miles to the southeast of Johannesburg.

In the Klerksdorp district, in 1898, five mines produced 42,962 ounces of gold, worth £177,404. These mines are situated from about 90 to 110 miles southwest of Johannesburg.

The Main Reef Series.—This is by far the most important group of mines under consideration, producing 93 per cent of the total output.

The Deep Levels.—In the Transvaal, as already observed, a mining claim consists of a parallelogram, 150 Cape feet wide, extending 400 Cape feet along the dip. Mining rights are confined to the ground contained within vertical planes drawn through the boundaries of the claim, there being, fortunately for the interests of the mine owner, no extra lateral rights. A claim of this size is obviously too small to admit of profitable working, and, therefore, companies are formed by the amalgamation of a number of claims,—in the case of the outcrop companies, usually 30 to 60; in the first row of deep levels, 150 to 250; and in the case of the second row of deep levels, a larger number still.

In 1898 there were employed upon the Rand 9476 whites and 88,627 Kaffirs. The white labourers are predominantly British, though the leading consulting and superintending engineers and many of the important members of the technical staffs are Americans, and the mine and mill foremen are usually either Americans or British subjects who have had mining experience in America. These men are generally thoroughly competent; but the average of white



A SORTING AND CRUSHER STATION

labour as a whole, especially among carpenters and machinists, is far below the American standard. Considerable improvement, however, is taking place in this regard. A large part of the manual labourers on the surface, and all the miners except those running machine drills, are blacks,—Basuto, Zulu, Shangani, and Zambesi "boys."

The quality of this black (native) labour is very poor. Most of the "boys" are utterly inexperienced when first employed; and they rarely remain long enough to acquire great proficiency. When they arrive, making in many cases tramps of several hundred miles to reach the mines, they are in an emaciated condition, and require to be "fattened up" for several weeks. After a few months' sojourn they become fine specimens physically; and, in some cases, they remain long enough at the mines to become expert miners. But it is exceptional to find great efficiency among the "boys" in drilling holes. They receive average monthly wages of £2 9s. and their board which amounts to about 12s. per month. Their task is a hole of 3 feet per day. The holes to be drilled are located by the shift boss, and the holes are fired by him, firing by the "boys" being usually forbidden. Some of them, however, acquire sufficient knowledge to fire a hole, and also to run a machine-drill. The latter work, however, is generally done by contract, and the contracts are given to whites.

By reason of the rapidly increasing demand for labour and the obstacles interposed by the government, there has been a great deficiency of native labour. As a result, large numbers of air-drills have been necessarily employed in stoping, to the great disadvantage of the mines, since much of the ground is of such a character as to make stoping by machine-drills economically unadvisable. Where the reefs are flat or small, the employment of drills necessitates the breaking down of much larger blocks of ground than would be necessary with hand-drills. Moreover, work under such conditions involves the excessive use of dynamite,—an important item where dynamite is as expensive as it has been upon the Rand,—and creates at the same time an undue amount of

fine waste, which not only lowers the yield of the ore in the battery, but increases the production of slimes.

White and native labour represent each about 30 per cent. of the working costs. By reason of the long transportation, but especially of the excessive railway rates from coast ports, mining supplies are excessively high upon the Rand. As an example of the exorbitant charges of the South African railways, I quote from the evidence, given by the late Mr. L. I. Seymour in 1897 before the industrial commission of inquiry of the South African Republic, the following charges per ton-mile on the different lines named. The amounts are stated in pence:—

On the Cape line, 2.34; the Orange Free State, 2.34; the Natal, 3.04; the Portuguese, 4.07; the Netherlands-Cape, 7.69; the Netherlands-Natal, 5.06; and the Netherlands-Delagoa, 4.27.

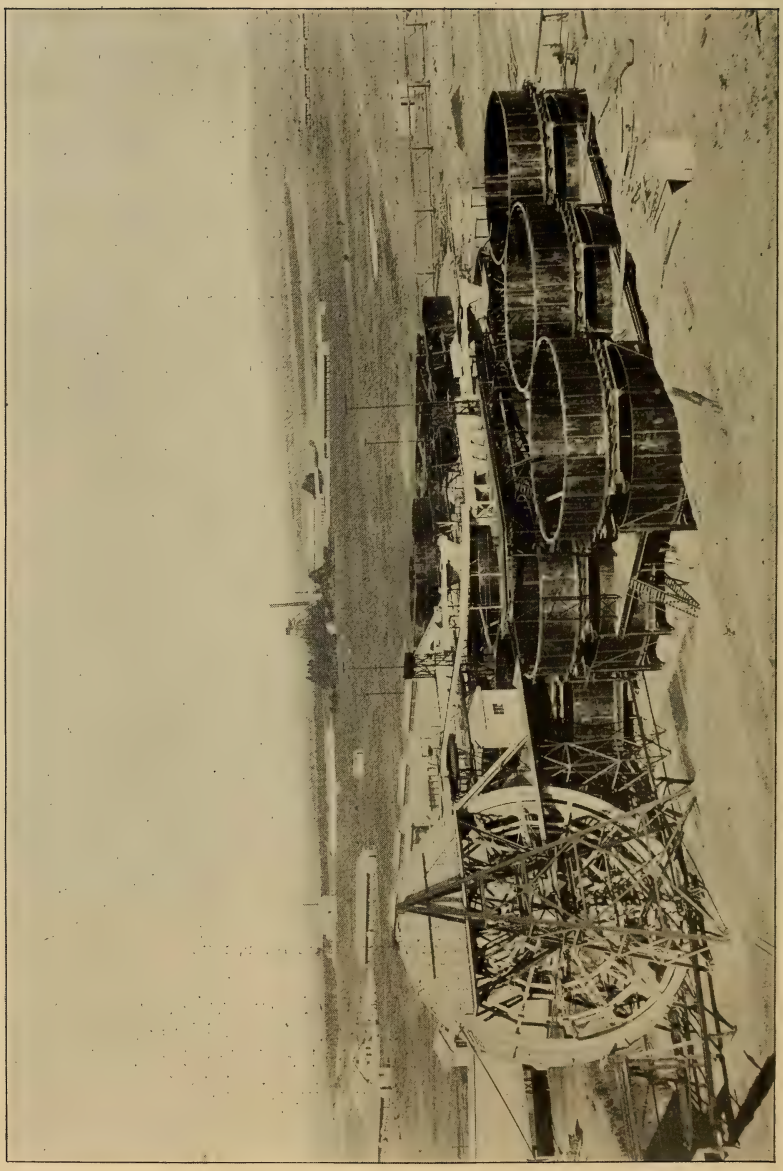
Generally speaking, the principal machinery at any time will be found to cost, erected, two and a half times its home cost. By reason of a monopoly granted by the government to foreign concessionaires, with whom leading Transvaal officials were privately associated, the cost of dynamite has constituted about 9 per cent. of the working expenses of the Rand mines. The cost of coal has amounted to 8 per cent. of the working costs. Fortunately for the mines, coal was discovered in South Africa shortly after the discovery of the gold deposits. The principal coal fields are from fifteen to twenty miles east of Johannesburg. Coal costs about 8s. per ton, delivered at the pit's mouth, and the railway rates are about 3d. per ton per mile. The best quality of coal obtainable in the Transvaal has about 70 per cent. of the efficiency of Welsh coal, but the average efficiency is lower than this.

GEOLOGICAL FEATURES *

The Witwatersrand auriferous conglomerates occur interstratified with beds of quartzite, sandstones, and schists. The schists are of several lithological varieties, but are often not of sedimentary origin, having been derived from basic igneous rocks through mineralogical and mechanical metamor-

STAMP BATTERY OF THE LANGLAAGTE DEEP, LTD.

* Further geological details are given in *The Gold Mines of the Rand*, by Hatch and Chalmers, published by MacMillan & Co., London; *The Geological Map of the Southern Transvaal*, by Hatch, published by E. Stanford, Cockspur Street, London; and *The Witwatersrand Gold-fields, Banket and Mining Practice*, by S. J. Truscott, published by MacMillan & Co., London.



A TYPICAL SOUTH AFRICAN CYANIDE PLANT

phism. The horizontal thickness of the outcrop of the Witwatersrand beds is variable. In the vicinity of Johannesburg southward, it is about 26,000 feet. Assuming the average dip of the reefs at 30°, this would give a true thickness at this point of about 15,000 feet. To the north, and underlying the main reef series, is an intrusive mass of granite, having a width at the surface north of Johannesburg of about seventeen miles; while to the south, at a distance of about three miles, there occurs an intrusion of amygdaloid diabase, about 20,000 feet in thickness.

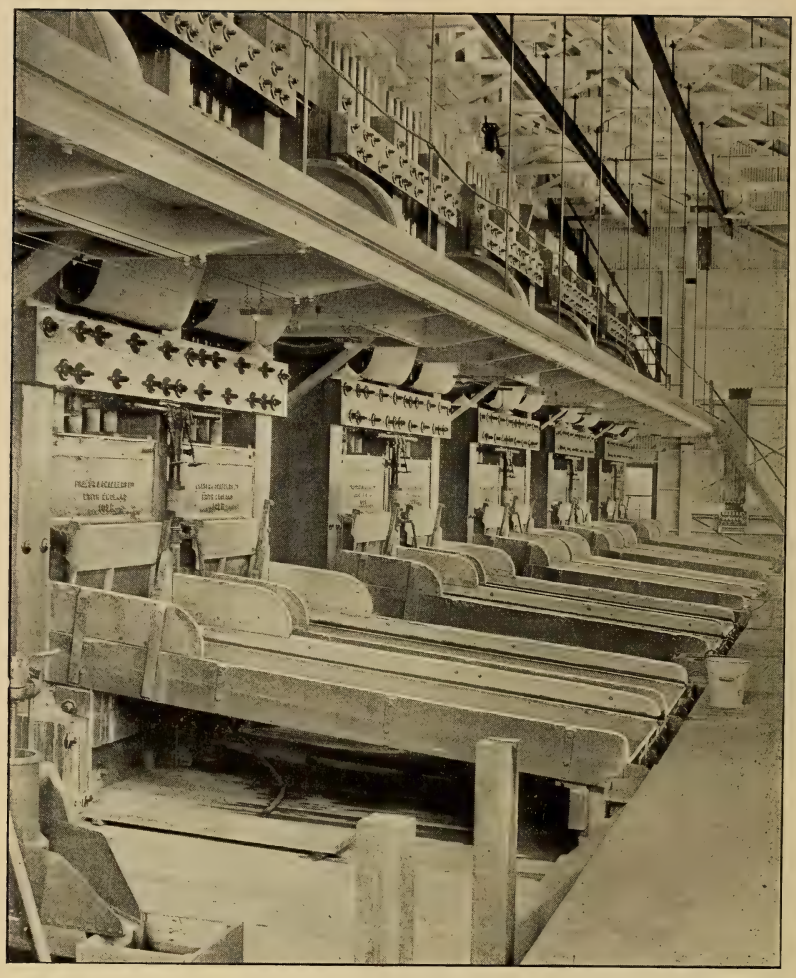
The outcrops of the conglomerate reefs form roughly the rim of a basin, though, by reason of faulting, there are many detached parts in the periphery of the basin; and by reason of superficial inequalities there is more or less sinuosity in its course, considerably marring its symmetry. For convenience of description, however, the term "basin" is applicable. The basin is elongated, with a longer axis of about 75 miles east and west, and a shorter one of about 25 miles north and south. The total length of its periphery is about 300 miles. Over the greater part of this distance it had been proved by outcrops or borings, though about one-quarter is obscured by other superimposed formations. According to the shape of the basin, the conglomerate reefs dip towards a common centre; *i. e.*, along the northern edge they dip southward, upon the southern edge northward, and upon the east and west edges they are west and east, respectively. In their upper horizons, and at the outcrop, the reefs dip frequently as much as 80°; but in depth they are flatter, and probably at a vertical depth of 2000 feet will have an average dip not exceeding 30°.

In the Witwatersrand there are two well-defined synclines, but the second one, known as the South Heidelberg, is limited in extent, and has no great economic importance. The above description refers to the main reef series, which is situated on the larger of the synclines referred to, and upon which nearly all the mining of the Witwatersrand is carried on. Several parallel series of reefs are embraced within this main reef series. A section in a southerly direction from the underlying granite which forms the basement rock shows, in the order of their position, the Dupreez, Main Reef, Livingston, Bird Reef, Kimberley, and Elsburg series.

The Dupreez series, known also as the Reitfontein series, is situated about two miles north of the Main Reef. It can be traced in an easterly and westerly direction as far as the Main Reef series itself; but it has been worked successfully at but a few points. The conglomerate beds are patchy in character, and, owing to their proximity to the underlying granite, have suffered considerable deformation. Next in position comes the Main Reef series.

The most southerly series is the Elsburg, about four miles south of the Main Reef series. This is characterised by very large pebbles, averaging several inches in diameter. The intervening series (the Livingston, Bird Reef, and Kimberley) are well defined and persistent, but carry so little gold as to make them unworkable, except at a few points, where small bunches of payore have been found. Figs. 1, 2, and 3 (taken from Truscott's book) show the relative positions of these series, excepting the Dupreez or Reitfontein, which lies further north, beyond the quartzite shale, and close to the granite, on different sections across the basin. It must be understood that these sections are mainly based, not upon actual outcrop discoveries on section lines, but, in many cases, upon calculations from intersections of the respective reefs in depth, and upon estimates of averages from varying underground data.

Thus Fig. 1 represents a section through Johannesburg, in which it is believed that the horizontal distances between the Main, Livingston, Bird, and Kimberley series are approximately correct,—the Main-Bird interval having been determined from the positions of these two series in the Robinson Deep shafts, where the section was, so far as known, free from local disturbance, the position of the Livingston having been



A STAMP BATTERY INTERIOR

determined likewise on a section underground believed to be undisturbed; and the Bird-Kimberley interval having been measured on a surface line, not found, after careful examination, to be crossed by any large dykes. The position of the Elsburg series in this section was, on the other hand, located by taking an average of the estimates of various authorities.*

Fig. 2 represents a parallel section, taken about a dozen miles east of Johannesburg, in which the distances have been measured on the surface. It will be seen that in this region, at the east end of the central section of the Rand, the intervals are greater and the dip is steeper.

Fig. 3 is a section across the formation taken a little west of Johannesburg and based chiefly on surface data. It is given here to illustrate the complicating effects of dykes and faults in this field.

These three figures taken together do not, of course, fully exhibit in detail the structural and stratigraphical features of the Witwatersrand beds. Mr.

* It will be noticed that the Kimberley-Elsburg interval is not laid out, like the rest, to scale. The break between the two, in the otherwise continuous datum-line of the section, represents more than 1,200 feet

Truscott's book, already cited, contains many other sections, which, however, it would be useless to introduce here without reproducing also his discussion of them. I have selected these three, almost at random, as furnishing hints of the nature of the problems presented to mining engineers in the planning of work in this complicated district.

The Main Reef series is situated on the southern slope of the Witwatersrand,—a ridge of quartzite situated just north of the town of Johannesburg and extending in an easterly and westerly direction. This ridge has a general elevation above the country to the south of from 300 to 500 feet. It is nearly 6000 feet above sea-level, and forms the watershed between the Atlantic and the Indian oceans.

In ascending order, the following are the most important conglomerate beds in the Main Reef series:—1, the Main Reef; 2, the Main Reef Leader; 3, the South Reef. There are several other reefs in the series, but they are generally barren or of very low grade, and of no economic importance. While these reefs are persistent, it is nevertheless difficult to correlate them at points far apart, owing to the variations in relative position, size, gold tenure, etc. Moreover, a variable nomenclature obtains in different parts of the district, which enhances the difficulty of identification, and faulting at certain points has contributed to make correlation obscure. Along the central section of the Rand it is less difficult than at the eastern and western extremities, where authorities differ as to the proper extension of the Main Reef series.

The Main Reef, which gives its name to the series, consists generally of several beds of "banket" separated by layers of quartzite, though sometimes forming a solid body of conglomerate as much as 12 feet in thickness. It is worked in but very few places, being of low grade, carrying rarely more than five or six pennyweights of gold to the ton, and on the average considerably less. Overlying this reef, separated by a few feet of quartzite in places and at times without any demarcation, is the Main Reef Leader. The pebbles of the Leader are usually larger than those of the Main Reef. In some of the mines the upper portions of the Main Reef are stoped in conjunction with the Main Reef Leader itself. The thickness of the Main Reef Leader varies from a few inches to about 3 feet. About 16 inches would represent the average width. In its value also it varies considerably, running from a few pennyweights to several ounces of gold per ton. From 30 to 100 feet or more south of the

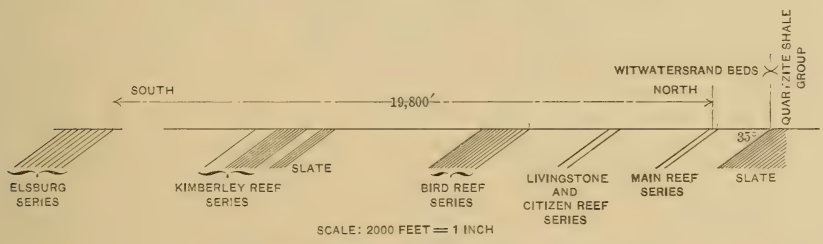


FIG. 1.—A SECTION ACROSS THE FORMATION AT JOHANNESBURG

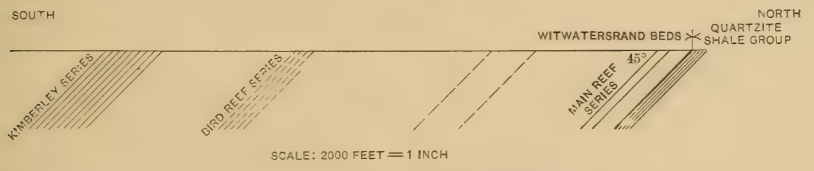


FIG. 2.—A SECTION NEAR ROODEPOORT

Main Reef Leader is the South Reef, varying in width from a few inches to 5 feet. Its pebbles are smaller than those of the Main Reef and the Main Reef Leader. It approaches the auriferous conglomerate similar to those of the Witwatersrand occur in the Orange Free State and in Natal, but where worked have not as yet proved profitable. On the west coast

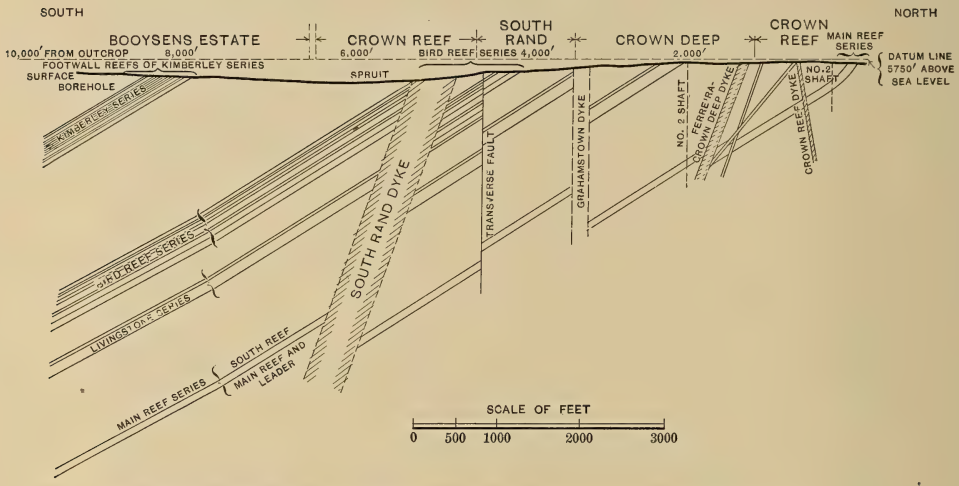


FIG. 3.—VERTICAL SECTION, FROM CROWN REEF ON THE MAIN SERIES TO THE KIMBERLEY SERIES

Main Reef in its easterly strike, and as it goes eastward it has less economic value.*

In the Main Reef series there are sometimes as many as three "payable" parallel reefs; but while these reefs may be continuous throughout a certain section, it is rare that they are all at one time, "payable," the pay ore being usually confined to two of them, and in some places to one only. The reefs vary in width from a few inches to 20 feet or more. The combined stoping width of the reefs worked may be stated, however, at an average of 5 or 6 feet. The matrix of the gold and the filling of the reef is chiefly well-rounded pebbles of quartz, cemented by secondary silica, and also by sesquioxide of iron and pyrites, and chloritic matter. The gold very rarely occurs in quartz pebbles, being usually confined to the cementing material of the conglomerates. The size of the pebbles varies from a diameter of about 0.33 to 3 or sometimes 5 or 6 inches. Beds of

* Reefs called Bastard Reefs are characterised by the occurrence of small pebbles, or where the pebbles are of ordinary size they occur sparsely distributed through the bed of quartzite. These reefs carry little or no gold.

of Africa (the "Gold Coast") auriferous conglomerates described as strongly resembling those of the Witwatersrand are also found, and in some places the gold tenure seems to be of sufficient grade to permit profitable mining were economic conditions more favourable.

Dykes and Faults.—These are so frequent as to affect materially the disposition of mining plants and the exploitations upon the different properties. In estimating the tonnage of expected product, at least 15 per cent. must be deducted from the total reef-area as an allowance for faults, etc. Frequently, however, the faults are so reversed as to give a reduplication of the reefs. The Simmer and Jack fault is one of the most important. This is caused by a dyke, striking east 32° south, dipping slightly northwest, and resulting in the throw of the line of reefs, on the east side of the dyke, about 1200 feet to the north.

There are also many interbedded dykes, which, however, have in few instances had any demonstrable effect on the gold contents of the reefs. Fig. 4* shows the occurrence of a gold-bearing

* From Mr. Truscott's book.

bedded dyke in the Ferreira. Overlying this gold-bearing dyke is a vein of quartz, which is distinctly auriferous. Among other instances of the proximity of a dyke affecting the gold tenure of the reefs one of the most notable is at the Buffle doorn mine, where the payable section of the reef is determined entirely by the proximity of the dyke.

The dykes have various strikes, sometimes more or less parallel with the strike of the reefs, and again crossing reefs almost at right angles. Some of the many interbedded dykes may have been formed during the formation of the conglomerate beds, but by far the greater number are intrusive. That they are of different ages is shown by the fact that they frequently fault one another. They vary in width from a few inches to about 300 feet—rarely more than that. Petrologically these igneous "ricks" or dykes belong to the group of basic greenstones.

The gold of the banket is finely divided, and generally crystalline, though sometimes flaky and scaly, indicating a detrital origin. Its fineness varies from about 0.800 to 0.860, from 150 to 115 thousandths being silver. Visible gold occurs sometimes, but rarely, in the matrix. Frequently the gold constitutes a thin facing or plating upon fissured planes of the quartz pebbles. It is found also, though rarely, in the secondary silica which envelops the quartz pebbles, and partly fills the interstitial spaces between them.

Besides free gold, auriferous iron pyrites occurs, constituting, in the unoxidised zones, an average of about 2.5 per cent. by weight of the vein filling. In the richer mines the pyrites carries from four to six ounces of gold per ton of concentrates. Marcarsite, copper pyrites, zincblende, galena, and a few other metallic minerals, are likewise occasionally found in small quantities in the banket. Arsenical pyrites is fortunately absent, and antimonial minerals are rare.

These reefs are called banket reefs on account of the resemblance of the mineral to the confection called "almond-rock" (*Banket* in Dutch).

MINING PLANTS AND METHODS

The methods of mining in the Witwatersrand district present no features specially different from those followed in the exploitation of similar deposits elsewhere. Fortunately the ground stands well, and little timbering is required,—a most important consideration in a country where mining timber is so scarce. The mines are what mining engineers would call "dry," the water being usually seepage, and varying from 50,000 gallons per day, for a shaft sunk upon the outcrop of the reefs, to less than 5000 gallons for a shaft sunk upon the second row of deep levels, where the reefs are reached at a vertical depth of about 2000 feet. This statement represents fairly the average quantity pumped in the district under the conditions described; but in some places, in sinking shafts, even upon the first row of deep levels, we have encountered an influx of water as great as 50,000 gallons per hour. These rare cases were in broken country, where the watershed conduced to a copious supply.

The amount of water available for boilers, batteries, cyanide treatment, etc., is, even in the present state of development of the industry, inadequate, and presents a difficult problem to the

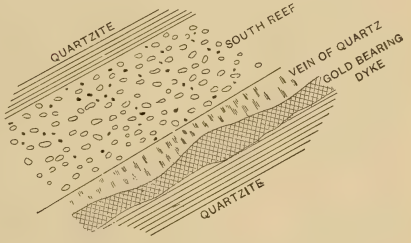
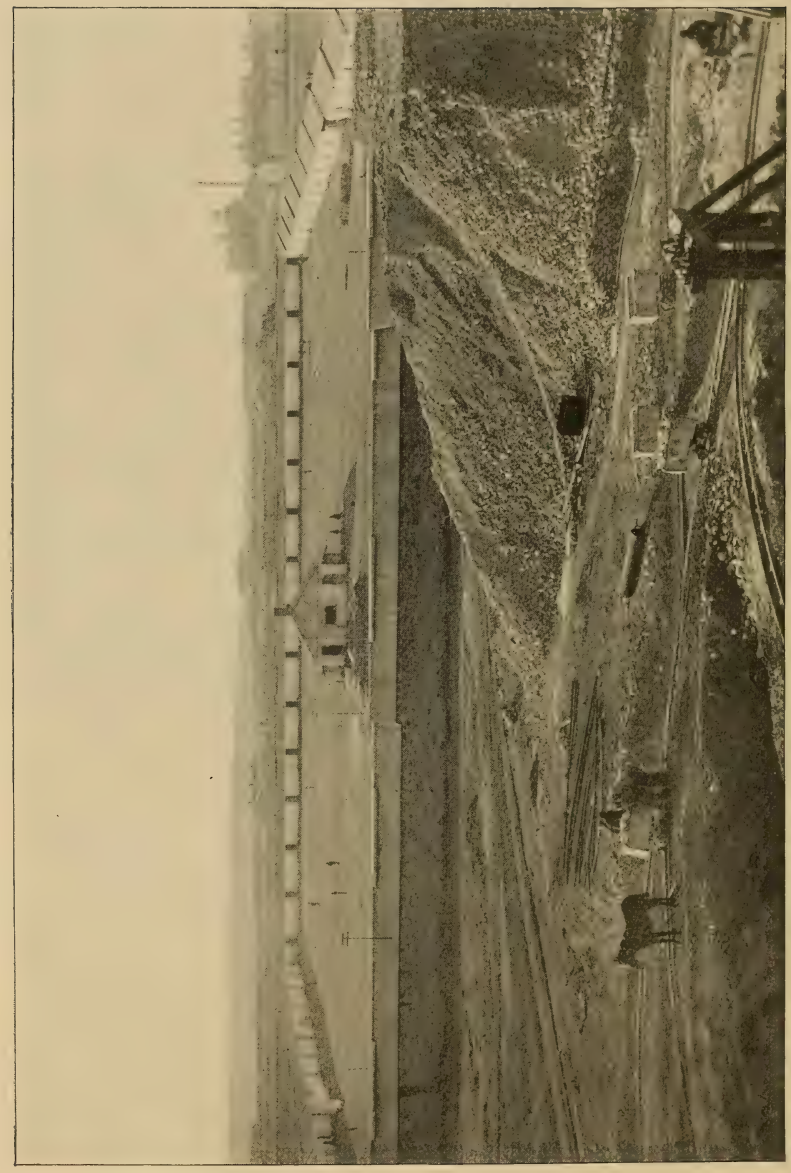


FIG. 4.—INTERBEDDED DYKE IN THE FERREIRA MINE

mine operators. The water from the mines is usually acid, and hence not desirable for boilers. The necessary supply of water is at present made up by local storage of rain-water. The average rainfall in the vicinity of Johannesburg is from 25 to 30 inches per annum; but, being more or less torrential in character, and limited to a few months, it is somewhat difficult to



A "COMPOUND" AT THE CROWN DEEP, LTD. THE QUARTERS OF THE NATIVE LABOURERS

impound. There are, however, within twenty or twenty-five miles of Johannesburg other sources of water supply, which will probably be utilised in the future. Cornish pumps are by far the most common type of pumping machinery, though electric pumps are coming into use, especially in shaft sinking, where the water to be handled is unknown and variable in quantity.

Air-drills are extensively used upon the Rand, especially for development work, which is energetically carried on. The Ingersoll-Sergeant, Riedler, Allis, and Walker drills are the most popular. Electric drills have been tried, but thus far without success.

The boilers used are of nearly all types. The water-tube boilers of Babcock & Wilcox and Heine, and the horizontal multitubular boilers are most extensively used. The earlier installations included the Lancashire, the Cornish, locomotive boilers, and others.

Great attention is given to the preparation of maps of the underground workings, geological sections, and plans upon which assays are plotted. In these respects the Rand practice is far ahead of that of any other country with which the writer is familiar.

Hoisting is done by cages and self-dumping skips. The head-gears have in the past been chiefly constructed of wood, but the use of steel head-gears is now becoming more general, especially in the deeper mines.

MILLING

Before going to the battery the ore is sorted, either in a central sorting station or more commonly in a sorting house immediately adjoining the head-gear. The ore is tipped upon a grizzly, the fines passing through to the ore bins. No attempt is made to assort the fines. The coarse material is usually sorted on a revolving table or a moving belt, water being sprinkled on the stuff before it reaches the sorters, who are Kaffirs, directed by white bosses.

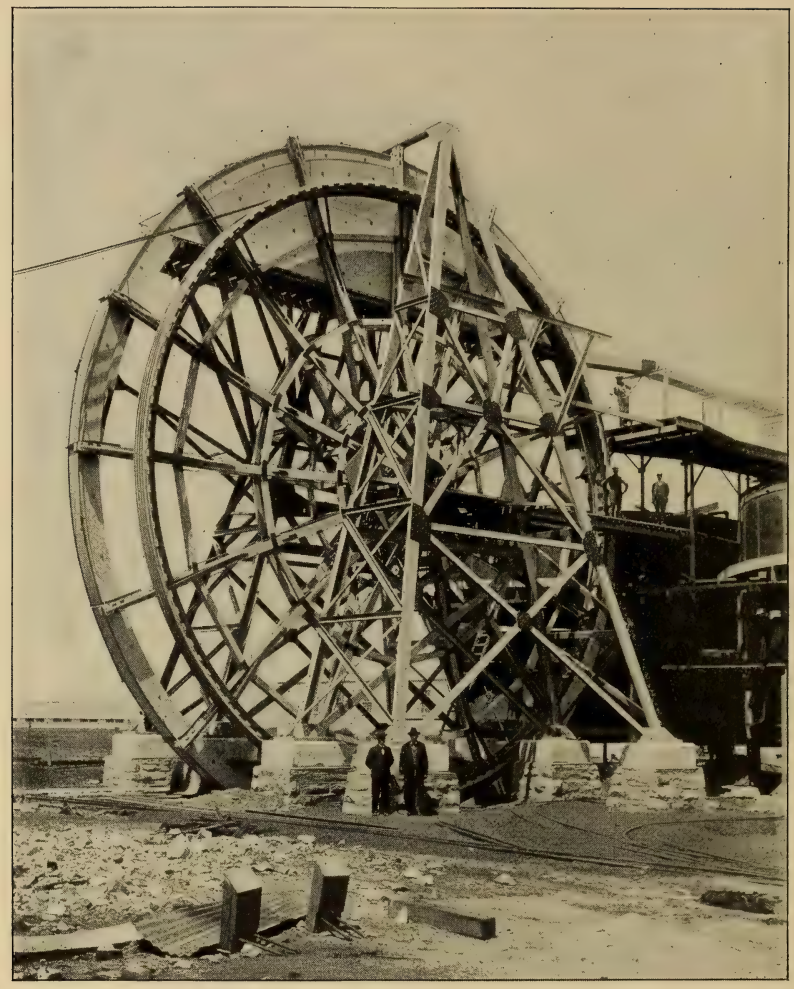
From 10 to 40 per cent. of the waste is eliminated by sorting, at an average cost of sixpence per ton sorted. The sorted ore is then crushed in machines, either of the gyrating class, of which the Gates crusher is a type, or of the reciprocating class, of which the Blake is a type. In some cases a second sorting follows crushing. Out of 8,979,328 tons of ore mined in 1898, 7,331,446 tons were milled. The difference, 1,647,882 tons, being 18.35 per cent. of the total amount of ore mined, was waste, sorted out at the surface.

The mills are usually situated close to the shafts, and the ore is elevated by different devices into the ore bins. The stamp batteries are of the usual type of gold mills. Mills of less than sixty stamps are rare on the Rand. The tendency is towards larger plants. The usual size of recently erected mills is 200 stamps.

The gold occurs in the cementing material which encloses the pebbles. Fine grinding is, therefore, not necessary. The aim among the mill men of the Rand is to utilise the greatest crushing capacity of the battery, and not to depend to any great extent on battery amalgamation, the expectation being that the free gold will be caught on the outside plates. In many cases, therefore, inside battery amalgamation is not practiced. The meshes of the screens range between 500 and 900 per square inch. The amount of water used in crushing is about eight tons per ton of ore crushed. Of this water about 75 per cent. is saved by settling, and used over again for the battery, the loss due to leakage, evaporation, and absorption by the tailings being about 25 per cent.

The average capacity per stamp per day for the district is 4.68 tons. This capacity is gradually being increased by the use of heavier stamps, coarser crushing, etc. In some of the recently erected batteries nearly six tons of ore per day is the duty per stamp. In the larger mills the batteries are placed back to back. The cost of a 200-stamp mill, to crush 1000 tons per day, is:—

200-stamp mill, "back to back"	£ 49,000
45-ft double tailing-wheel	2,250
750 H.-P. mill-engine and condenser	6,800
1,000 H.-P. boiler-plant	15,000
Engine and boiler-houses	3,000
Plant for hauling ore to mill	2,000
Water-service and reservoirs	25,000
Total	£103,050



A 60-FOOT TAILINGS WHEEL OF THE FRENCH RAND GOLD MINING COMPANY. THIS WAS THE PIONEER OF A SERIES OF 60-FOOT DIAMETER WHEELS BUILT BY THE RAND MINES. THEY ARE THE LARGEST ON THE WITWATERSRAND

By amalgamation on copper plates about 65 per cent. of the total gold recovery is effected. There is no arsenic, antimony, or zinc in the ore, and the quicksilver loss is small,—not over two pounds per stamp per month. Concentrators are employed in but few of the mills. They are chiefly used along the eastern portion of the central section, where the pyrites does not seem to yield readily to cyanide treatment. In some of these mines from 10 to 12 per cent. of the total gold contents of the ore is obtained from the concentrates, which assay from four to five ounces per ton, and represent 2.5 per cent. in weight of the ore treated. The cost of concentration is about ninepence per ton of ore. The concentrates are treated by chlorination at a cost of from £2 to £2 10s per ton, with a saving of 98 to 99 per cent. of the assay value. The total amount of fine gold obtained from the concentrates for the mines in the district for the year 1898 was 139,427 ounces, having a value of £489,097.

TREATMENT BY THE CYANIDE PROCESS

The following description applies to the treatment of ores in the pyritic zones. Ores from the upper (oxidised) horizons of the reefs, which constitute but a small percentage of the ores treated, require a slight modification of the process.

The ground near the mines is level, and does not permit transportation by gravity. Consequently, the ore must be first elevated into the ore bins at the mill, and the tailings leaving the mill must be elevated for treatment by the cyanide process. This is done either by tailing pumps, or, preferably, by tailing wheels. These are from 40 to 50 feet in diameter, and discharge the tailings into a launder, which, with a grade of about 3.5 per cent., carries them to the cyanide works. The auriferous pyrites is to a large extent taken out as concentrates by means of *Spitzlutten* (hydraulic classifier). About 10 per cent. of the mill pulp recovered in this way consists of pyrites with coarse sand, a concentration of 10 to 1 being obtained. These concentrates are taken to tanks for separate treatment. From two to three weeks of treatment is required in order to obtain from this material a recovery of from 90 to 95 per cent. of the gold it contains. A solution of about 0.25 to 0.3 per cent. of cyanide of potassium is used. After passing over the *Spitzlutten* the tailings are run to *Spitzkasten* (pointed boxes), where the heavier sands are allowed to settle, while the lighter material (slimes) overflows and is carried to the slime-works for special treatment. The sands which settle in the *Spitzkasten*, representing about 70 per cent. of the battery pulp, are continuously discharged by pipes leading from the bottom of the box, and are delivered by a hose or by an automatic revolving distributor to settling tanks, into which they are so fed as to be as thoroughly mixed as possible. This separation of the sands from the slimes has to be carefully made, so as to remove all clayey substances, the presence of which would otherwise prevent rapid percolation of the solution and the free access of atmospheric oxygen, which is essential to the solution of gold by cyanide.

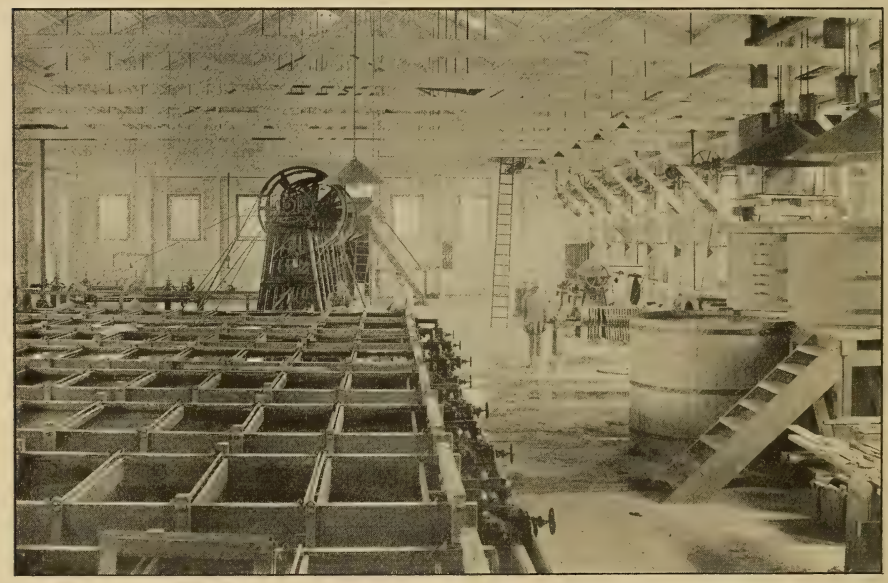
Most of the modern plants have a system of double treatment, the tailings being settled in the settling tanks, when they are treated, after being allowed to drain, with a weak solution of cyanide

THE LANGLAAGTE CYANIDE TANKS. THE 54-FOOT TAILINGS WHEEL IS DRIVEN BY MANILA ROPE

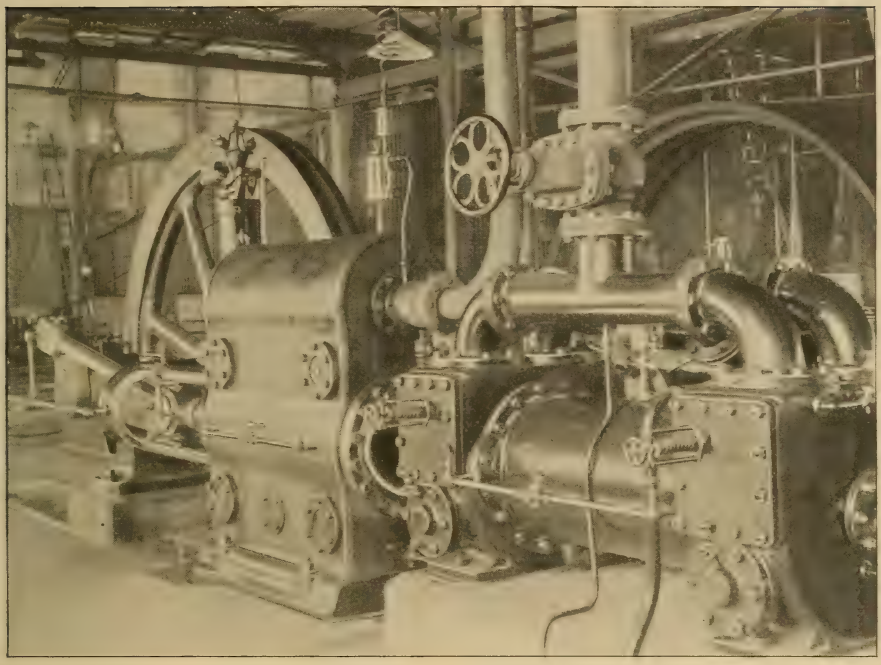
of potassium. This addition of the cyanide of potassium is made rather for the purpose of saturating the sands with the solution and subsequent aeration than for thorough leaching which would be difficult, on account of the packing of the sands as they are settled rendering percolation difficult. The aeration is obtained by the discharge (usually by shoveling) from the upper to the lower tank, thereby securing a more rapid and complete solution of the gold in the later treatment. After the solution has been drained off, the sands from the settling tanks are discharged into the leaching tanks, placed immediately below the settling-tanks, from which they are filled from discharge doors on the bottom of the latter. For a 200-stamp plant sixteen steel settling and sixteen steel leaching tanks are usually employed. From three to four settling and leaching tanks are used for the treatment of the *Spitzlutten* concentrates above described. The settling tanks are usually 40 feet in diameter and 9 feet high. The leaching tanks have the same diameter, but usually a foot less height. The capacity of these tanks is about 400 tons of pulp each.

In the leaching tanks the pulp is subjected to three treatments with cyanide of potassium. Where the McArthur-Forrest process is used, the strong solution contains 0.25 per cent.; the medium solution, 0.2 per cent.; and the weak solution, 0.10 per cent. of KCy. In the Siemens-Halske process the solutions are weaker, namely, the strong solution, 0.10; medium, 0.02; and weak, 0.01 per cent. of KCy.

The treatment requires from four to seven days. From 130 to 150 tons of solution are usually employed for 100 tons of sand. After being allowed to drain, the sands are discharged through bottom discharge doors into trucks, in which they are removed to residues or tailings heaps. Here, again, elevation is necessary, on account of the flatness of the country, and is usually effected by the endless-rope system. These tailings heaps are conspicuous throughout the mining district. By reason of the heavy winds prevailing at certain seasons of the year, they are becoming a great nuisance; and the question of



AN EXTRACTOR HOUSE FOR A 200-STAMP MILL. ON THE RIGHT ARE THE SULPHURIC ACID VATS AND IN THE CENTER THE ZINC EXTRACTOR BOXES



A RIEDLER AIR COMPRESSOR AT THE CITY AND SUBURBAN GOLD MINES, BUILT BY MESSRS. FRASER & CHALMERS, LTD., LONDON

their future disposition is one of the problems for the mining engineer.

The cyanide solution, after being drawn off from the leaching tanks, is taken to the precipitation boxes. The gold from the strong solution is precipitated in one set, and that from the weak solution in another set of boxes. Precipitation is effected by either the McArthur-Forrest or the Siemens-Halske process.

The McArthur-Forrest Process.—In this process the gold is precipitated by zinc, the solution passing upwards through a succession of compartments, in which are placed zinc shavings or filings, resting on a movable tray of coarse screening. About twenty precipitation boxes, 20 feet by 3 feet by 3 feet 9 inches in size, are used. The gold-bearing solution is brought into close contact with the zinc, causing the deposition of the gold, partly as a metallic coating on the zinc, and partly as gold slimes, which sink to the bottom of the box. As the zinc is gradually dissolved by cyanide more is added. Once or twice a month the boxes are emptied, and the gold slimes are treated with dilute sulphuric acid, then dried and melted in crucibles. The dried slimes contain about 15 to 20 per cent. of gold, and after fluxing with borax and soda, an ingot of 0.750 to 0.800 fineness in gold and 0.100 in silver is obtained. The slag, carrying from 5 to 50 ounces of gold per ton, is usually sold to smelters.

This precipitation process yields satisfactory results only with solutions containing more than 1 per cent. of cyanide, the weaker solutions not being acted upon by zinc. An improvement of the method is the addition of lead to the zinc, whereby the combination of the two metals forms a galvanic couple, which also reacts with weaker solutions, such as are employed, for example, in the treatment of slimes.

The Siemens-Halske Process.—In this process the solution flows through compartments very similar to the zinc boxes above described, but the zinc shavings are here replaced with lead

strips (0.1 pound per square foot) or shavings hung between iron plates placed vertically and longitudinally in the box, about 4 inches apart. The lead strips are connected with the negative, and the iron plates with the positive, pole of a dynamo; and the solution is thus electrolytically decomposed, the gold being plated on the lead cathode. The iron plates are wrapped in canvas to prevent short circuiting. The current employed is from 2 to 3 volts, giving a current density of about 0.06 ampères per square foot of cathode. Once a month the lead sheets are removed and replaced, and the gold-coated lead is melted and cupelled, yielding a bullion of 0.880 fine in gold and 0.100 in silver. The litharge is sold to smelters. The solutions passing through the treatment boxes are collected in tanks, and are made up to a proper strength by adding the necessary KCy.

The cost of the Siemens-Halske process is slightly greater than that of zinc precipitation, and the percentage of extraction is about the same. But the Siemens-Halske process may be applied to any solution, weak or strong.

THE FUTURE OF THE WITWATERSRAND GOLD FIELDS

During the eight months ending in August, 1899, after which the commencement of active hostilities interfered with the active working of the mines, the Witwatersrand produced £12,485,032 sterling. At this rate, the year's production would have been £18,727,548. As a matter of fact, it would have amounted to about twenty millions sterling, by reason of the progressive increase in the monthly production already shown during that year. Of this output 71 per cent were derived from what is known as the central section, extending about 1.5 miles west and about 8 miles east of Johannesburg; and 24 per cent. were derived from the deep-level properties within that section. The total gold product of the Witwatersrand was 25.5 per cent. of that of the entire world. Notwithstanding the increased production of gold elsewhere, this ratio would have been more than maintained had mining operations not been interfered with by the South African war.

Within one year after the resumption of mining operations, upon the scale existing immediately prior to the war, an output of gold at the rate of over twenty millions sterling annually may be reasonably estimated; and this rate of production will be steadily increased, partly by the increase in the crushing plants of some of the companies, but more especially by the starting of many of the deep-level properties which will then reach the producing stage. Within the next three or four years, after operations have been resumed on a large scale, the annual gold production from the Witwatersrand may reach twenty-five millions sterling. Beyond this there should be a further increase, the amount of which it is impossible to estimate. In from six to eight years some of the important gold producers among the outcrop companies will fall out of line, by reason of the exhaustion of their mining areas. To what extent this deficit will be counterbalanced by increased yield in the deeper level properties cannot be as yet determined. Much depends upon the policy adopted by the larger companies owning these properties.

In the reliability of its ore bearing formation the Rand is unique in the history of gold mining, but in the minds of many an exaggerated importance is attached to the persistency of payable ore bodies in strike and in dip. There is, indeed, considerable fluctuation in the value of the ore within the same reef, even within short distances; but a remarkably even grade of ore has been maintained since the inception of the industry. Where there has been an apparent falling-off in yield per ton during any year, the fact is to be attributed rather to the working of lower grade ores, made possible by improved economic conditions, than to a depreciation in the ore values of the reefs themselves.

The results of the developments in the deep-level areas have been so satisfactory as to engender a certain recklessness on the part of mining companies

owning very deep reefs. The exploitation of certain of these areas is not regarded by conservative engineers as at present justified, in view of the large intervening tracts of undetermined value which separate mines in operation from the site of proposed mining upon these very deep-level areas.

To what extent mining can be carried on in depth in the Transvaal is a most interesting and important problem. The conditions there are certainly most favourable for mining at great depth. From present indications the influx of excessive quantities of water is not to be apprehended. In respect to temperature, the district is especially fortunate, in that the increment of temperature with depth thus far observed has been abnormally low. In the case of the Robinson Deep mine, it is about 1° F. for 212 feet of vertical depth.

With the exception of the additional costs of haulage, pumping, and ventilation, there are no factors operating against mining on the Witwatersrand to a depth of at least 8000 feet vertically. These costs will not afford any insuperable obstacle to profitable mining, provided, of course, the geological character of the deposit is not adversely changed. So reliable is the formation, from a geological point of view, as regards its mining potentialities, that engineers have felt justified in assuming the existence of payable ore at depths of 1000 feet vertically and upwards beyond the extent in depth of any mining operations. Thus far the results of actual operations upon these areas have justified their position.

It is estimated that for every mile in length along the course of the reefs, down to a vertical depth of 1000 feet for the dip of these reefs, gold to the value of about £10,000 000 will be extracted. This is a conservative estimate,—at least as applied to the central section of the Rand. If we assume these conditions to obtain to a depth of 6000 feet vertically, we have the enormous sum of £60,000,000 for each mile in length. It is not unreasonable to suppose that these conditions will be maintained along most of the central section, say for a distance of ten miles, in which case we would have an auriferous area, within practicable mining depths, containing upwards of £600,000,000 value of gold.

It is less safe to make any prediction of the gold product to be expected from the east and west sections; but it is perfectly safe to say that the output of these sections would very greatly augment the amount I have named. Messrs. Hatch and Chalmers, well-known engineers of extensive South African experience, compute the available gold from these portions of the Rand at £200,000,000.

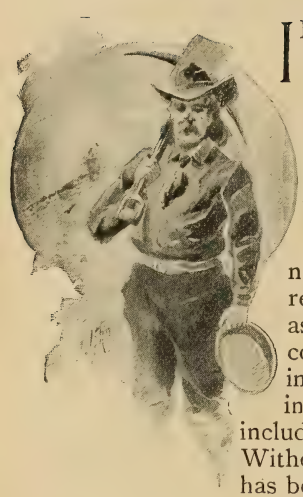
It is impossible to predict with any accuracy the duration of mining in the Witwatersrand district, by reason, especially, of the indeterminate factor of the rate at which exploitation will be carried on. It may be observed, however, that the tendency is to exploit the auriferous areas as rapidly as possible, and that engineering methods are all adopted with that end in view. If the exploitation of the deeper levels is not delayed pending the proving of the ground lying above, but is carried on concurrently with the exploitation of the higher horizons of the reefs, the industrial life of the district will, of course, be correspondingly shortened. The working of lower grade ores, made possible by improved economic conditions or other circumstances, would tend to increased longevity of the industry. But were I called upon to express an opinion, I would estimate the future duration of profitable operations on a large scale in the district at less, rather than more, than twenty-five years

The future looks from all points of view encouraging. We may reasonably anticipate important improvements in economic conditions as the result of the establishment of a better government. I believe that, as the result of economic reforms, there will be an ultimate saving of 6s. per ton of ore treated, as compared with the conditions under which mining has been carried on under the government of the late South African Republic. For the tonnage of ore crushed in 1898, this would result in an increase of annual dividends of £2,199,405.

HYDRAULIC MINING

PLACER AND ALLUVIAL MINING, AND GOLD DREDGING

By George H. Evans



IF there is one branch of mining more than another that calls forth the abilities, taxes the ingenuity, and at the same time exposes the weak points and ignorance of the mining engineer, it is that branch referred to in general as hydraulic mining, covering placer mining and alluvial mining, and, of late years, including gold dredging. Without doubt more money has been wasted and more ignorance displayed in connection with such ventures than any other kind of mining.

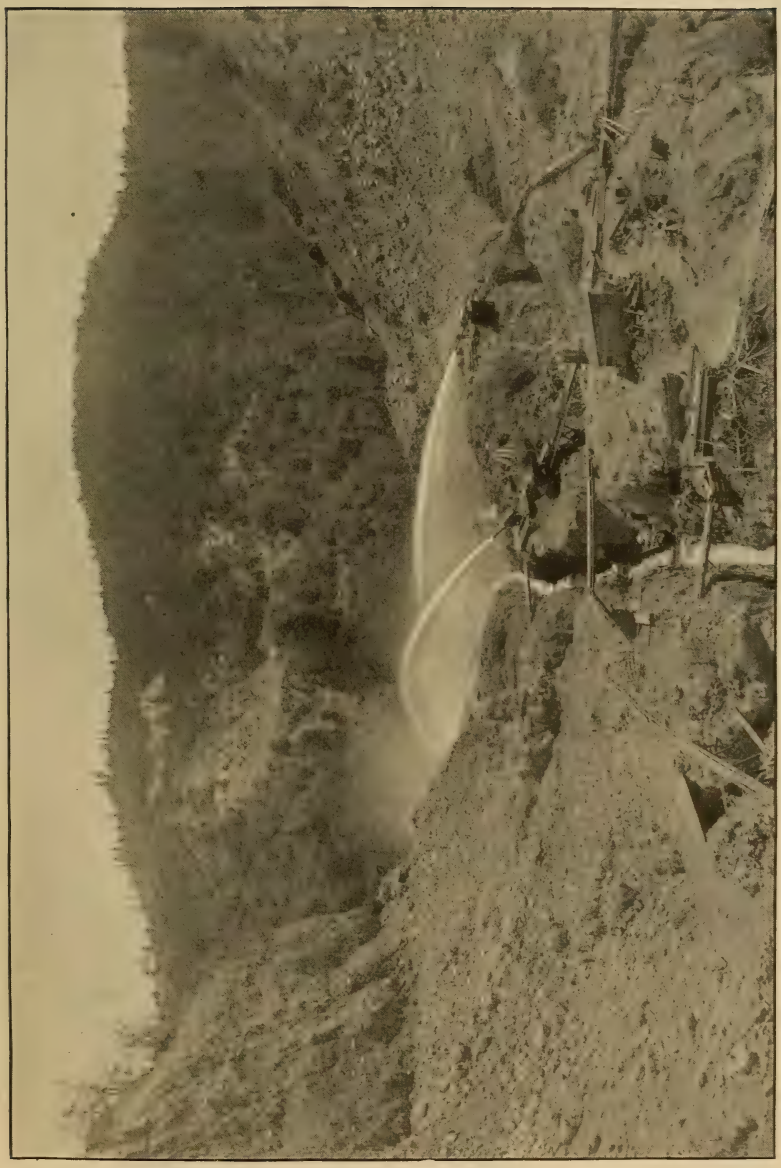
It seems to be taken for granted, even by many men who have world-wide records as successful financial and business men, that mining ventures are easily handled, that it requires little or no training to successfully manage them, and it is a common occurrence to find mines in which large sums are invested in the hands of some friend of the president or relation of a director, who has been brought up in a large city and in many cases has never seen a mine, and has neither practical training nor experience. There are innumerable monuments of failures in which the above state of affairs may be traced for cause, in which many well-known, successful financiers and business men have squandered fortunes of their own and of their friends. The sooner mining investors realise these facts, the sooner will mining of all classes become a more legitimate form of investment.

The different forms of mining entitled to be grouped under the head of hydraulic mining include the most interesting and fascinating methods, and many of the various problems in connection with them that are continuously cropping up will always make this branch of mining the most enticing to professional mining men, as well as to investors. Branches of this kind of mining may be easily traced back to pre-historic periods, and from times immemorial, gold washing has been carried on in nearly every known portion of the globe.

There are numerous publications giving in detail the early history of gold washing, and latterly what is termed hydraulic mining, tracing it, step by step, to its present state of efficiency in many parts of the world, so that the writer feels it unnecessary to take up much of the space allowed for this article in dealing with historical facts relating to the subject, but proposes to give a *résumé* of practical hints and suggestions, together with data accumulated by him in different parts of the world.

Most of the data that will be referred to for this article have been collected during terms of practical working at, and in the vicinity of, extensive mining properties, and have been of valuable assistance, especially when located in countries many miles from professional advice and references.

In taking charge of, experting, or purchasing any mine that is to be worked by the hydraulic or dredging methods, the following are some of the most important points to be thoroughly satisfied upon:—Average values contained in the gold-bearing material; possibilities of saving it by the ordinary and cheap gravitation methods; water supply and facilities for delivering it on



THE POLAR STAR HYDRAULIC MINE, DUTCH FLAT, CALIFORNIA

BREAKING DOWN GRAVEL BANKS AT BULLION, BRITISH COLUMBIA, WITH HYDRAULIC "GIANTS"

property with sufficient working head or pressure; area of ground available for "dump"; liberal grades for bed-rock, sluices, etc.

It has been the writer's experience to find that altogether too little practical prospecting is done to determine the average values of large tracts of alluvial deposits, and to this cause alone many failures may be traced. It should be the endeavour of the expert, purchaser or intending investor to thoroughly prospect the material by a series of shafts to bed-rock in several portions of the property and not to rely on pan results taken from parts easy of access and possibly representing concentrated values. Of late years a very valuable aid towards determination of values in connection with placer mining is a portable drilling outfit similar to those used in the oil regions. After many careful tests, the writer is satisfied that with a good, experienced crew in drilling holes in gravel, and taking care to follow up the bits closely with the casing, it is possible to obtain sufficiently reliable results as to probable average values contained in the ground to be treated, and where fuel is fairly reasonable this work can be carried on at prices ranging from two to three dollars per foot through the most obstinate deposits of gravel and to depths ranging from 30 to 70 feet. The results of careful prospecting will soon reveal the values, and experience will then dictate the best form of gold-saving appliances.

The water facilities, another most important factor, must be determined in a careful and conservative manner; one must be satisfied with nothing short of a suitable and most favourable location for sufficient water under pressure the season round. It is necessary to take into consideration the topography of the surrounding country, look up all records of rain and snow fall, area of water-sheds in the vicinity of the property and other features, being most careful to determine the minimum quantity of water that may be relied upon either throughout the whole year or the portion of the year constituting the probable working season in the particular locality where it is intended to carry on mining operations.

To carry out the above investigations in an intelligent and fairly accurate manner, reliable data must be obtained as to average flow in the different creeks and rivers at lowest stages, and these data must particularly refer to the highest points at which it appears necessary to divert such water, allowing for the maximum grade suitable for the country through which the ditches are to be run, so that the water may be delivered on to the property at an elevation sufficient to guarantee an efficient supply and

A HYDRAULIC "GIANT" AS MADE BY THE RISDON IRON WORKS, SAN FRANCISCO, CAL.

working head or pressure for operating giants, water-wheels, pumps, elevators or other necessary mining machinery, even at the highest points; in other words, the available water supply must be brought to the property with sufficient working head to permit mining out every portion of it.

There are on record many instances of dismal failures, owing to the construction of long and expensive ditches or canals without regard to efficiently handling the higher portions of the claims, which, although containing payable ground, would not warrant the construction of other expensive ditches at higher elevation, thus causing abandonment of the property. Such errors have, in many instances, prevented good mines from yielding profitable returns to their owners, and have also given a black eye to what would have

ANOTHER VIEW OF GRAVEL WASHING AT DUTCH FLAT, CALIFORNIA

been, with proper management, a prosperous mining district.

Having decided the values in the ground and that there is plenty of water available for mining purposes at sufficient elevation, the next important step is to make a thorough examination of the country through which the ditch has to be constructed with a view of deciding upon the maximum grade possible for it and picking out a course that will require the minimum length of flume or timbering of any kind. By careful attention to these points, one will be enabled to locate a ditch capable of conducting to the mine the maximum supply of water with a minimum area for excavation and correspondingly low cost of construction.

Whatever grades are determined upon, allowances must be made at all points where fluming, boxing or rock-cutting is necessary for an additional fall or grade in order that these portions of the ditch will carry all the water with the least cross-section possible, thus reducing the more costly portions of the ditch.

Along the line of the ditch points must be located for making bye-washes to relieve the ditch from sudden and heavy rains, and due precautions observed at each waterway along the line of the ditch for fluming across or under the ditch the freshets in such waterways, caused by melting snows or heavy rains. This is a point often neglected, and has been the cause of many a bad break in ditches, entailing heavy expenses for repairs and loss of valuable sluicing time.

Referring to facilities for "dumping," this important item must receive careful attention and a rough estimate be formed of the quantity of material that will have to be removed in the natural course of working out the mine. Liberal allowances must be made for the grade of tail sluices from lower to upper boundaries of the property. Of course, the richness of the ground will regulate the expense warranted for creating artificial dumping facilities, but for ground sluicing or straight hydraulicking on any but rich ground, this becomes a most important factor, and even very small expense at this end of the property will often make it impossible to profitably work a mine, as such expense is an increasing one.

With reference to methods of working low-lying deposits, when sufficient fall is not available for the heavy grades necessary for hydraulicking or ground sluicing, these will be dealt with under the headings of dredging, elevating, etc.

Having gone into the general routine and course of procedure with reference to determination of values, water facilities, dump, etc., it may be both interesting and useful to become acquainted with some of the more simple methods of making and checking the many different calculations that become necessary to the proper equipment, in the way of pipe-lines, sluices, etc. A very simple method of arriving at the quantity of water flowing in a creek or stream, where it is possible to find a portion of it having a fairly uniform cross-section, is as follows:—Measure the depths of water in feet, at from six to twelve points across the stream, and the widths at equal distances apart; do this in five or six places along a fairly straight course, and at more places where the course is very irregular. Add all the depths together and obtain the average; do the same with the widths, and multiply the average depth by the average width; the result will be the area of the cross-section in square feet, and this, multiplied by the velocity of the water in feet per minute, will give the number of cubic feet of water approximately flowing in the stream. This result again multiplied by 0.666, will give the quantity of "miners' inches"; or the number of cubic feet per minute, multiplied by 7.48, will give the result in United States gallons per minute.

To arrive at the velocity, a fairly accurate and easy way is to step or measure off 120 feet along the banks of the water course, and in order to make allowance for the water flowing faster at the surface than at the bottom or sides and thus arrive at the mean velocity,

HYDRAULIC MINING AT BULLION, BRITISH COLUMBIA, BY THE CARIBOO HYDRAULIC MINING COMPANY. A DOUBLE LINE OF SLUICES

we call the measurement 100 feet. At the commencement of the 120 foot mark, throw into the middle of the stream, pieces of paper, wood, loaded bottles or other kinds of floats at intervals; note the time it takes each one to reach the end of the 120 feet, which are assumed, for calculating purposes, as 100 feet; divide the total time taken by all of the floats by the number of feet and thus get the average for each float; this result, in minutes or fractions of a minute, divided by the assumed distance of 100 feet, will be the velocity of the water in feet per minute, and this, multiplied by the area in square feet, will give the number of cubic feet per minute flowing in the stream or creek.

Another rapid and simple method for gauging small streams is to construct a dam across and back up the water sufficiently high to destroy its velocity. On top of the dam place a thin board having a notch cut out, of a width that will carry the whole of the water with a moderate depth of overflow. The following calculation will give the number of gallons per minute flowing

through the notch, and this result, divided by 11.25, will convert the gallons per minute into "miners' inches." For example:—A weir having a notch 4 inches in depth and 72 inches wide will discharge according to the following formula:—$G = d\sqrt{d} \times l \times 2.67$ or 1538 gallons per minute, where G represents gallons per minute; d, depth of overflow in inches; and l, length of notch in inches.

There are, of course, many other and more correct methods of measuring the flow of water in channels or streams, by means of more elaborate forms of weirs, V-notches, and by motors and by the use of various coefficients to suit each separate set of conditions; but the writer has endeavoured to illustrate two of the most simple, in order that anyone of ordinary intelligence can determine the approximate quantity of water flowing without difficult formulæ to unravel.

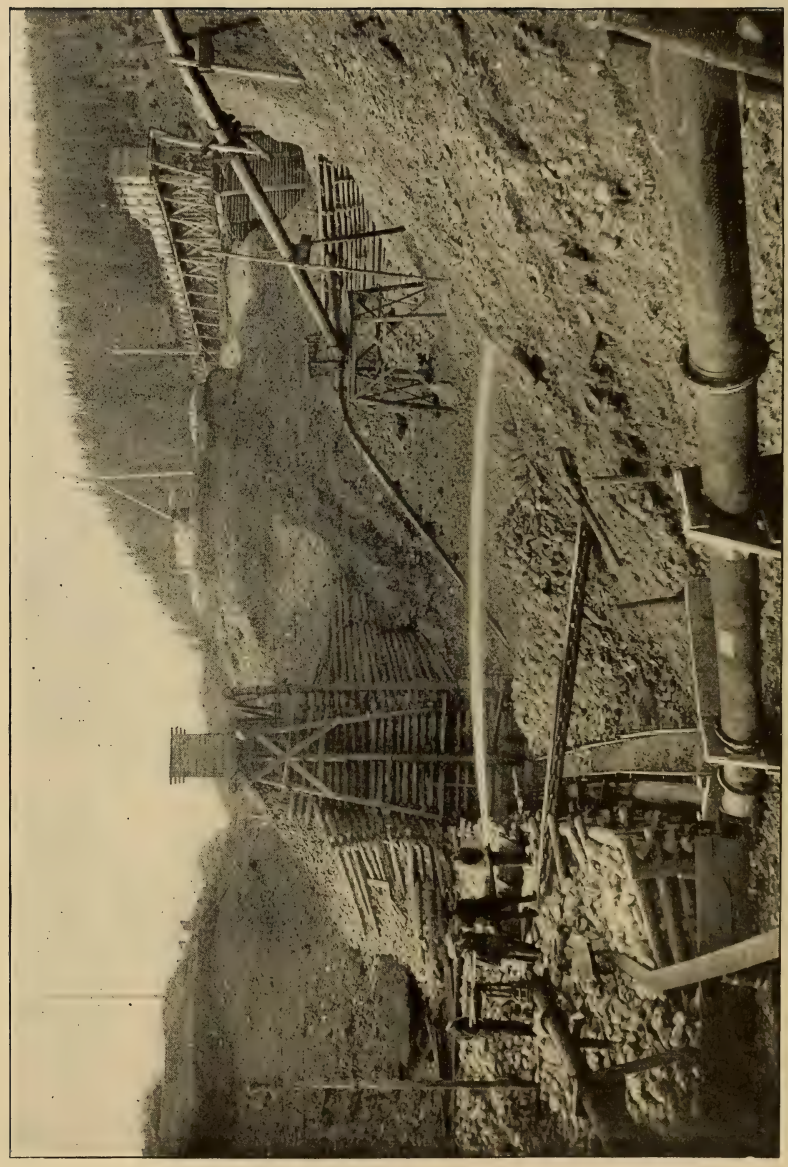
With reference to grades and capacities of ditches, the character of the country through which the ditch has to be constructed will, of course, have an important bearing on the grades to be adopted; but as a guide, it will be well to remember that in ordinary ground the water should travel at the rate of from 180 to 200 feet per minute. As before stated, in those portions of the ditch that are in rock, or require fluming, one will allow for a much greater velocity for the sake of keeping down the cost of construction, and it must also be remembered that at all points where grades are increased, or, in fact, changed at all, arrangements must be made for drops in the ditch and construction of wide places in it at such points, in order to give the water an opportunity of being checked before entering the portion of the ditch, flume or rock-cutting, or any other part where the grade has been altered, thus allowing the water to enter or leave each section with the velocity due to its grade and in this manner preventing scouring and undermining.

Knowing the velocity of the water required in the ditch, the dimensions may be easily determined by dividing the quantity of water to be used, in cubic feet per minute, by the velocity in feet per minute. For example, to construct a ditch with a capacity of 600 cubic feet per minute, or 400 "miners' inches," and having decided that the velocity shall be about 200 feet per minute, we divide 600 by 200, giving 3 as the number of square feet there must be in the ditch cross-section in order to carry the quantity of water, without allowances for friction, leakage, and evaporation.

While on this subject, it should be remembered that the least amount of friction is generated when the least wetted border, or perimeter, is obtained, and, to get this result, the bottom of the ditch or flume should be from one and three-quarters to two and one-quarter times the depth of the sides. This point, if carefully studied, will often save ditch owners large sums of money in both lumber and cost of construction.

The following is a simple rule to find the height of the sides of a ditch or flume when its area has been determined and it is desirable to follow the directions stated above:—When the width is to be 1¾ times the height of the sides, multiply the area in square inches by 4 and divide the result by 7; then take the square root of the product and the result will be the height of the sides.

PANNING GOLD



PIPING GRAVEL TO A HYDRAULIC ELEVATOR WHICH RAISES IT TO A GOLD-SAVING FLUME

When the width is to be 2¼ times the height of the sides, multiply the area in square inches by 4 and divide the result by 9; the square root of the product will, as before, give the height of the sides.

In ditch calculations it is often necessary to obtain the wetted border, or perimeter, or, in other words, the length of so much of the bottom and sides of the ditch or flume as is occupied by the water; for instance, in a ditch or flume flowing 30 inches in width and having a depth of water of 18 inches, the wetted border, or perimeter, will be 30 + 18 + 18, or 66 inches or 5.5 feet, and the same ditch or flume when empty would have no wetted perimeters. In ditches the sides are usually sloped in accordance with the nature of the soil and to conform to a well-regulated section for obtaining the best results, and it, therefore, often puzzles the novice in such cases to arrive at the correct wetted border. The following figures may, therefore, be found useful to many:—

For plumb sides, the wetted perimeter = depth × 2 + width of bottom.
For sloping sides, ¼ to 1, wetted perimeter = depth × 2.0615 + width of bottom.
For sloping sides, ½ to 1, wetted perimeter = depth × 2.36 + width of bottom.
For sloping sides, 1 to 1, wetted perimeter = depth × 2.828 + width of bottom.

The above results are practically correct for flumes and short ditches in good ground, but allowances must always be made according to the roughness and contour of the ditch, and in calculating the flow of water further allowances are necessary to provide for leakage and evaporation, which often, in dry climates and poor ditch country, amount to 30 per cent. of the available supply.

A more difficult, but correct, formula which has been obtained from actual gaugings, made in connection with many forms of ditches constructed in ordinary ground with usual winding course and short bends, is as follows:— Velocity in feet per second = 6 times the square root of $2\ G\ R\ S$, where G is the acceleration due to gravity, usually taken as 32.2 at sea-level; R, the hydraulic radius, found by dividing the sectional area of the ditch in square feet by the wetted primeter in feet; and S, the sine of inclination, found by dividing the total fall, or grade in feet of the ditch by the total length in feet.

If the ditch is constructed through rough country, and the bottom or the sides present rough surfaces to the water, then 5 times the square root of $2\ G\ R\ S$ will give the mean velocity in feet per second, and, of course, the velocity multiplied by the area will, in all cases, give the approximate discharge in cubic feet per second, and this, again, multiplied by 40, will give the discharge in "miners' inches."

The above formula is also correct for flumes, with sawed boards and battens over the joints inside the boxes, using 8 instead of 5 or 6 as a coefficient, and the formula will then read 8 times the square root of $2\ G\ R\ S$. This, multiplied by the area of the flume in square feet, will give the discharge in cubic feet per second.

As before stated, it is of great importance that a liberal allowance be made for losses due to leakage and evaporation, more especially where the line of the ditch does not pick up other small creeks or springs along its course, and it is agreed by some of the best authorities that a suitable allowance may be calculated by the following formula:—

$$M\ \frac{\text{Sectional area of the ditch in feet.}}{\text{Mean velocity in ft. per sec.} \times 5280.}$$

= the loss in cubic feet per second per mile, where M is a coefficient varying from 3 to 20, according to the climatic conditions of the country through which the ditch is constructed.

In the construction of ditches where, owing to weak banks, it is necessary to build walls on the lower side of the ditch, the ground should be removed to a solid formation, and two walls, an outer one and an inner one, should be built up, with space enough between them to allow a good puddle clay to be rammed in. Such walls, if properly constructed, will give no trouble.

All surface earth, trees, roots, etc., must be moved quite clear of the lower side of the ditch, with the exception of just sufficient to make a track along its line. Unless all such waste material is removed to such a distance that it will

not become a heavy drag on the lower side of the ditch, slides will be frequent and costly.

Many readers will appreciate the following simple methods of calculating the areas of the different cross-sections in connection with the various forms of ditches, flumes, etc.:—

To find the area of a section of a flume or ditch with vertical sides, multiply the width of bottom by the height of the sides in inches and the product will be the area in square inches, which,

A HYDRAULIC GRAVEL ELEVATOR

divided by 144, will give the area in square feet.

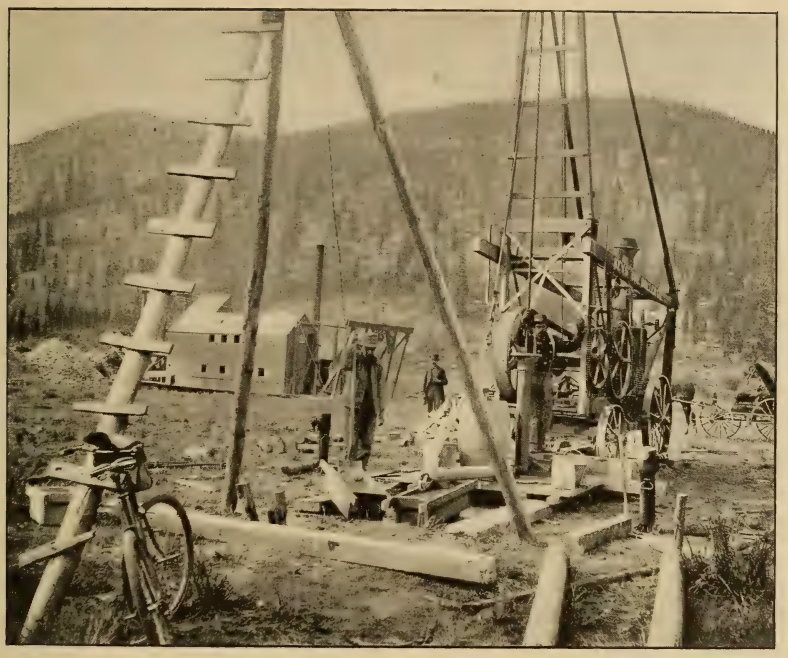
To find the approximate area of a flume or ditch with vertical sides, add together the widths at top and bottom in inches and divide by 2; this, multiplied by depth in inches, will give the area in square inches, and this, divided by 144, will give the area in square feet.

To find the approximate area of a ditch or flume with sides sloping to a point at the bottom, multiply the width in inches by half the depth in inches; the result will be the area in square which, divided by 144, gives the inches, area in square feet. Where the head of the ditch is above the timber line, and ice is likely to form early in the fall, it is of advantage to make the ditch as narrow as possible so as to allow an ice crust to form from bank to bank. In this way a flow of water may be depended upon for a much longer period than when the top of the ditch is made wide.

With reference to pipe-lines, nozzles, gates, valves and other details, the writer has no hesitation in stating that a preponderatingly large number of failures in hydraulic mining can be traced to the ignorance displayed in the design and construction of pipe-lines, principally due to not taking into consideration the loss of pressure caused by using pipes of too small a diameter. It is hardly possible to point out any portion of a hydraulic plant that is of more importance or that requires more care and judgment than the pipe-line. In out-of-the-way localities miners have great difficulty in finding out the correct sizes of pipes, particularly their capacities and the quantities of water that pipes and nozzles will discharge.

All pipe-lines should be laid as straight as possible, with curves of as large a radius as can be easily obtained. The first thing for the miner to do is to ascertain the fall available for the pipe-line and its maximum length in feet. Knowing this and the quantity of water to be used, it is easy to determine approximately the required diameter of the pipe, always bearing in mind that in order to secure the best efficiency at "giants," elevators and water-wheels, the velocity should not exceed 5 feet per second, and if the pipe-line is long the velocity should not exceed 3 feet per second, while, on the other hand, if the pipe-line is short and one can afford to lose some of the pressure, the velocity might be allowed to reach as high as 10 feet per second.

Having decided upon the maximum water velocity to be allowed in the pipe-line, and knowing the quantity required at the several working points in cubic feet per second, it is only necessary to divide this quantity in cubic feet per



DRILLING HOLES IN GRAVEL BEDS. THIS METHOD HAS BEEN FOUND ECONOMICAL AND RELIABLE

second by the velocity in feet per second and the result will be sectional area in square feet of the pipe necessary to deliver the water at the claim. For instance, if it be decided to use 400 "miners' inches," or 10 cubic feet, of water per second, and the greatest velocity that can be allowed is 5 feet per second, then 10 divided by 5 gives the area of the pipe, or 2 square feet. This is the equivalent of a pipe about 20 inches in diameter. This rule is given only as a guide, and to enable one to quickly and roughly determine the diameter of a pipe necessary. It is not intended that any long pipe-line of costly construction should be designed from the above suggestions alone; but there are many instances where much money would have been saved had reasoning similar to the above been applied before rushing blindly to the pipe makers and ordering costly pipe-lines upon the advice of some enthusiast or interested party without in any way being able to check up the advice and statements made as to the size of pipe required. A few of the more simple methods of determining the velocities and discharges from pipes are the following:—

To obtain the velocity, first multiply the diameter in feet by the working head or pressure in feet; divide the result by the length of the line in feet, then take the square root of the product and multiply by 50. This will give the velocity in feet per second, and this, multiplied by the area in square feet, will give the discharge in cubic feet per second. Again, multiplying by 40 will give the discharge in "miners' inches."

Multiply the number of cubic feet of water discharged per minute by 144 and divide the product by the area of the pipe in square inches; the result will be the velocity in feet per minute.

Multiply the number of "miners' inches" discharged by 11 and divide the product by 3 times the square of the diameter of the pipe in inches; this will give the velocity in feet per second.

Multiply the velocity in feet per second by 3, and this again by the square

of the pipe diameter in inches and divide by 11; the result will be the discharge in "miners' inches."

A more complicated, but accurate, rule for determining the velocity in feet per second in pipes is the following:—140 times the square root of $R \times S$ minus 11 times the cube root of $R \times S$, where R is the hydraulic radius, found by dividing the diameter of the pipe in feet by 4; and S is the sine of inclination, found by dividing the total fall of the pipe-line in feet by the total length of the line in feet. Allowances have to be made for different kinds of pipes and conditions, and nearly every instance requires a different coefficient.

In all cases the pipe-line will require a funnel or bell-shaped entrance at the head of the line to put the water in train, and in addition to the head required to overcome friction, it will be necessary to make allowances for what is commonly termed the velocity head, or the additional head required to start the water at the head of the line. A simple method of calculating this is to square the velocity in feet per second that has been decided upon for the pipe-line, and divide by 64.4; again divide by 0.70, and the result will be the extra head required.

Where the length of line exceeds 1000 diameters it is usual to take no notice of losses due to velocity heads, bends, etc.; but in practice the writer finds it much better to err on the right side, and in no case neglects to work out all such losses and make liberal allowances for them before deciding on the diameters of pipes required to do the work in an efficient and successful manner.

Care must be taken in constructing a pipe-line to place air valves of good dimensions and sure action at all high places along the line. At all low places similar blow-off valves must be placed. Should the pipe-line be laid on the top of the ground and exposed to extreme changes of temperature, then allowances must be made in all riveted lines for a good expansion joint each half mile; but if the pipe is properly buried, as all lines should be, then the expansion joints may be dispensed with. Another good precaution in pipe-lines is to place near the end of the line a safety valve of the old lever pattern, having an outlet equal in area to the several working outlets used at the claim, and set at a pressure slightly in excess of the total due to the head on the working points. This will relieve the pipe-line from any shocks that might be caused by carelessness in shutting down the valves, and in this way often save the destruction of the whole or a portion of the pipe-line. All gates and valves should be of the outside yoke and thread pattern, all stems having fine threads in order to prevent rapid opening or closing. Disregard of this item has caused the wreck of many a good line.

Nozzles require great care in construction so as to be of most efficient form, and should be perfectly smooth in bore so as to prevent the water in leaving them from scattering and thus losing power. In order to get the best effect from any kind of a nozzle it is absolutely necessary that the head of the pipe should be at least 3 or 4 feet under water, in order to prevent the admission of air which would pass through the nozzle and cause the water to scatter and destroy its working force.

To determine the approximate velocity and discharge in cubic feet per second from well-formed nozzles, the following methods will be found fairly simple:—Multiply the square root of the working head in feet by 8.03 for the velocity in feet per second, and multiply by the area of the nozzle, in square feet, for discharge in cubic feet per second; or, to find the discharge in gallons per minute, use the following formula:—$G =$ the square root of $H \times$ the square of $d \times 0.24$, where $G =$ gallons per minute; $H =$ working head or pressure in feet; and $d =$ diameter of nozzle in eighths of an inch.

For more accurate results the following formula should be used:—$Q =$ square root of $2 \times G\ H\ A \times 0.96$, where G is the acceleration due to gravity, usually taken at sea-level as 32.2; $H =$ working head or pressure in feet; and $A =$ area in nozzle in square feet;

or Q = the square root of the working head $\times$ the square of $d \times C$, where d = the diameter of the nozzle in eighths of an inch, and C = a variable coefficient, from 0.00064 to 0.00066. In each of the above cases Q represents the quantity of water discharged in cubic feet per second.

Losses due to friction in pipe-lines are a most serious and important factor, and very few miners are conversant with the principles relating to frictional losses of this nature. Most miners know that when large quantities of water are discharged from pipes of small diameter the pressure is greatly reduced, but few know how to find out the exact loss due to such cause. If this were not the case, there would not be in evidence so many palpable blunders in the construction of pipe-lines used for mining and other purposes. In many instances success would be the rule instead of failure. In some instances known to the writer, pipes too small in diameter brought the effective pressure down to less than one-half the pressure which would have been available with correct proportions.

There are several methods of determining the friction in pipes, but most of the formulæ are difficult and too complex for the intended scope of this article, except the following two, namely, Cox's simplification of the Weisbach formula and another appearing in Gordon's "Hydraulics."

Cox's formula is

$$H = \frac{l}{d} \frac{4\, v^2 \times 5\, v^{-2}}{1200}$$

Here H represents the total loss by friction in feet; d, the pipe diameter in feet; l, the length of the pipe-line in feet; and v, the velocity of the water in feet per second.

Gordon's formula is

$$H = \frac{p\, l\, c\, v^2}{2ga}$$

Here H represents the loss of head by friction in each 100 feet of pipe; p, the circumference of the pipe in feet; l, equals 100 feet; c, a variable coefficient, from 0.00406 to 0.01338, according to the nature of the pipe and velocity of the water; v, velocity of water in feet per second; g, acceleration due to gravity, or 32.2 at sea-level; a, sectional area of pipe in square feet.

The losses in bends and angles must also be calculated and allowed for, and, wherever possible, allow no bends having a radius of less than five diameters.

To calculate the loss of head due to bends of various angles, the simplest rules are, obtain the velocity of the water passing through the bend in feet per second, multiply the square of such velocity by 0.0152, and the result will be the loss of head in feet or additional head required to overcome the resistance of the bend.

When the radius of the bend is greater than five diameters, the loss may be found by multiplying the square of the velocity in feet per second by the number of degrees in the angle, and dividing the product by 88489. For example:—With a bend having an angle of 120° and discharging water at a velocity of 10 feet per second, the loss of head, or required additional head to overcome the resistance due to such bend will be

$$\frac{v^2 \times 120}{88489} = 0.135 \text{ feet.}$$

When the radius is less than five diameters, the resistance is approximately according to the following rule:—Mean velocity squared, multiplied by 64.4, multiplied by the square of half the angle of deflection, multiplied by 2.06 times the fourth power of the same angle. For fairly accurate results this more difficult formula may be simplified by multiplying the square of the velocity of the water passing through the bend in feet per second by C, a coefficient having the following values for the different angles:—

For angle of 10 degrees, $C = 0.000109$.
" " 20 degrees, $C = 0.000466$.
" " 30 degrees, $C = 0.001134$.
" " 40 degrees, $C = 0.002158$
" " 50 degrees, $C = 0.003634$.
" " 60 degrees, $C = 0.005652$.
" " 70 degrees, $C = 0.008276$.
" " 80 degrees, $C = 0.011591$.
" " 90 degrees, $C = 0.015248$.

The bursting and safe working strains of iron and steel pipes, plates and construction generally should be understood, and in arriving at them the following rules and suggestions will prob-

A BUCYRUS GOLD DREDGE COMMENCING OPERATIONS AT BRECKINRIDGE, COLORADO

ably be found of value; but, of course, they are dependent upon good construction, correct diameters, proper pitch of rivets and other details.

In making iron or steel pipes it is necessary that the plates be rolled lengthwise, or, in other words, across the grain. All pipes should be carefully dipped in a preparation of coal tar and asphaltum. Purchasers should insist on each pipe being completely immersed in the mixture at a temperature of between 300 and 320° F., and allowed to remain in this mixture until the metal of the pipe attains the same temperature. This is an important point, and carelessness in regard to it means a poor coating, which will peel and crack off in a short time. The following preparation is held by some to make a good coating:—

Crude Asphaltum, 28 per cent.
Coal Tar (free from oily substances), 72 per cent.
Refined Asphaltum, or 16½ per cent.
Coal Tar (free from oily substances), 83½ per cent.

To get the desired results in dipping, and give some idea of the time required for immersion, it has been demonstrated that pipes made from No. 14 gauge usually require about seven minutes, and pipes made from No. 6 gauge from twelve to fifteen minutes immersion.

For calculating the safe working pressures and the thickness of plates required, the following is one of the simplest formulæ for wrought iron and steel pipes:—

$$P = \frac{T \times t}{R} \div c \times f$$

where P is the safe working pressure in pounds per square inch; T, tensile strength of plate, iron usually calculated at 48,000 pounds and steel at 62,000 pounds per square inch; t, thickness of plates in inches or decimals of an inch; R, radius of pipe in inches; c, coefficient, or factor of safety, usually taken as 3 to 3.5 for this class of work; f, proportional strength of plates after riveting; for double riveting, 0.7, and for single riveting, 0.5.

To find the thickness of plates from which pipe must be made in order to stand any required working pressure, the following formula may be used:—

$$t = \frac{P \times R \times c}{T \times f}$$

Example:—Having a head of 179 feet, or 77.7 pounds pressure to the square inch, what thickness must the steel plates be for making up a pipe with a diameter of 36 inches?

Substituting numerical values in the above formula, we have the following:—

$$\frac{77.7 \times 18 \times 3}{62{,}000 \times 0.7} = 0.966 \text{ inch.}$$

In connection with working alluvial deposits in locations where there is not sufficient fall to permit the ground sluicing or hydraulic methods, in countries where débris laws are operative, and also in localities where it is impossible to obtain large quantities of water under pressure, it will be necessary to resort to either the hydraulic elevator or dredging process.

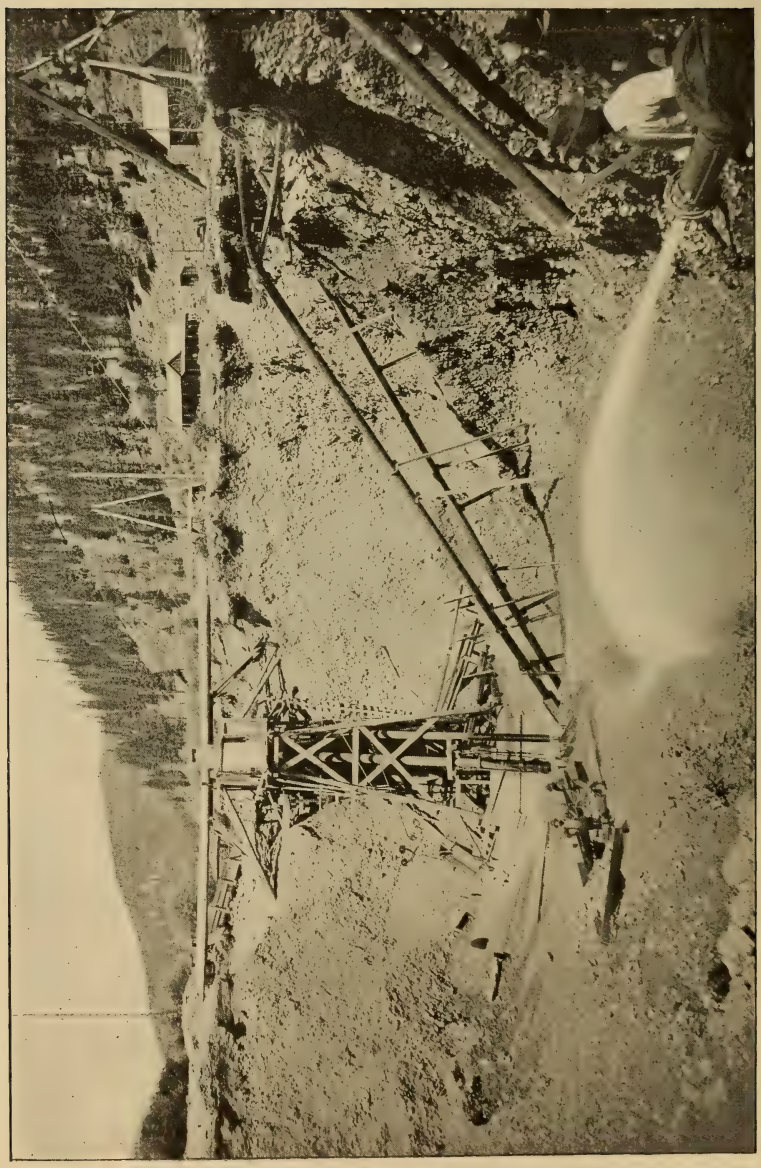
With reference to the latter, it may be stated that during the past three or four years this method of handling low-lying placers has become quite popular, and in various parts of the United States, particularly in the States of California, Idaho, Colorado, and Montana, no less than twenty dredges are working successfully, both in river beds and in inland locations several thousand feet from the rivers and creeks in the vicinity. Without doubt this method of placer mining is carried on more successfully in New Zealand than in any other portion of the world, working the gravels of different rivers, and at the present time nearly a hundred of these dredges are at work, most of them successfully, and many earning dividends ranging from 100 to 200 per cent.*

In dealing with dredging propositions care must be taken in the preliminary prospecting operations to become thoroughly acquainted with the nature of the bed-rock. This is most important, and in nearly every instance governs the chances of success in using dredges for placer mining. Should the bed-rock be found of such a nature that the lips of the dredge buckets cannot easily cut or scrape it, one may be assured that it will be impossible to recover the best, or bed-rock values, contained in the gravels. There are some large tracts of alluvial deposits suitable for dredging that will, on prospecting, show sufficient values from surface to bed-rock to warrant the installation of a dredge, even should the bed-rock values be impossible to recover; but great care and thorough prospecting ought to be carried out on a liberal scale before attempting to work such deposits by this method.

Many types of dredges are now on the market for working placer deposits,

A RISDON DREDGE STACKING UP TAILINGS FROM THE GOLD-SAVING TABLES

* Gold dredging in New Zealand has been made the subject of a separate article in this issue. —THE EDITOR.



ANOTHER VIEW OF A HYDRAULIC ELEVATOR WITH A "GIANT" PIPING GRAVEL TO IT

—clam shell dredges, the steam shovel kind, Archimedian screws, bucket and ladder dredges, and others,—but of all these the bucket and ladder dredge, in the writer's opinion, is the best machine for this particular service.

In New Zealand, where all classes of mining receive valuable aid in the way of subsidies from the government, this method of dredging the placers has been in vogue for over twenty years, and during that period every class of dredge has received a thorough practical test, at the cost of large sums of money, and at the present time one will see nothing but the bucket and ladder type, with mechanical stackers for taking care of the tailings, successfully treating the gravels. It is certainly no compliment to the ingenuity or business abilities of manufacturers of dredging machinery to find them inventing and manufacturing the many different and similar kind of machines that have been liberally and practically tried and proved failures by the dredging faculty of New Zealand years ago; yet there are evidences enough in California, Idaho, Montana and other parts of the United States of failures entirely due to the installation of unsuitable machines. Such failures could have been easily avoided had the manufacturers or investors only taken the trouble to make inquiries in a country that had bought its experience and paid very dearly for it in relation to gold dredging, and years ago condemned the very make of machines at present used and built in the United States. It is not claimed that the New Zealand type of dredge is a perfect one; but it is the result of experience gained by many years of practical working and of trials of everything in the shape of a dredge that came along.

The most important faults in connection with dredges of the present day are in connection with the gold-saving appliances. With few exceptions, these are of the crudest kind, the makers apparently using all their endeavours towards designing machines for digging capacity and allowing the gold-saving or most important end of the dredge to take care of itself.

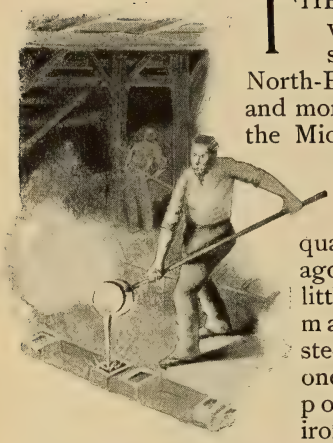
Where it is possible to obtain water under pressure, low-lying placers may be easily worked by the hydraulic elevator method, and as a general guide it may be assumed possible to lift gravels at least 15 feet above bed-rock with each 100 feet of pressure available in the supply pipe. Estimating on this basis, one is quite safe, as there are many instances in evidence of better results. At Breckenridge, Col., for example, there are two hydraulic elevators successfully working gravel deposits with 160 feet of head, lifting the material a height of 42 feet above bed-rock, while on the Feather River, in California, material was lifted a height of 76 feet with but 350 feet of head.

Under ordinary conditions the cost of working by this process seldom exceeds five cents per cubic yard, and there is no difficulty in handling from 1000 to 2000 cubic yards per each twenty-four hours.

THE STEEL TRADE IN THE NORTH-EAST OF ENGLAND

ITS RISE AND PROGRESS

By Henry Simpson



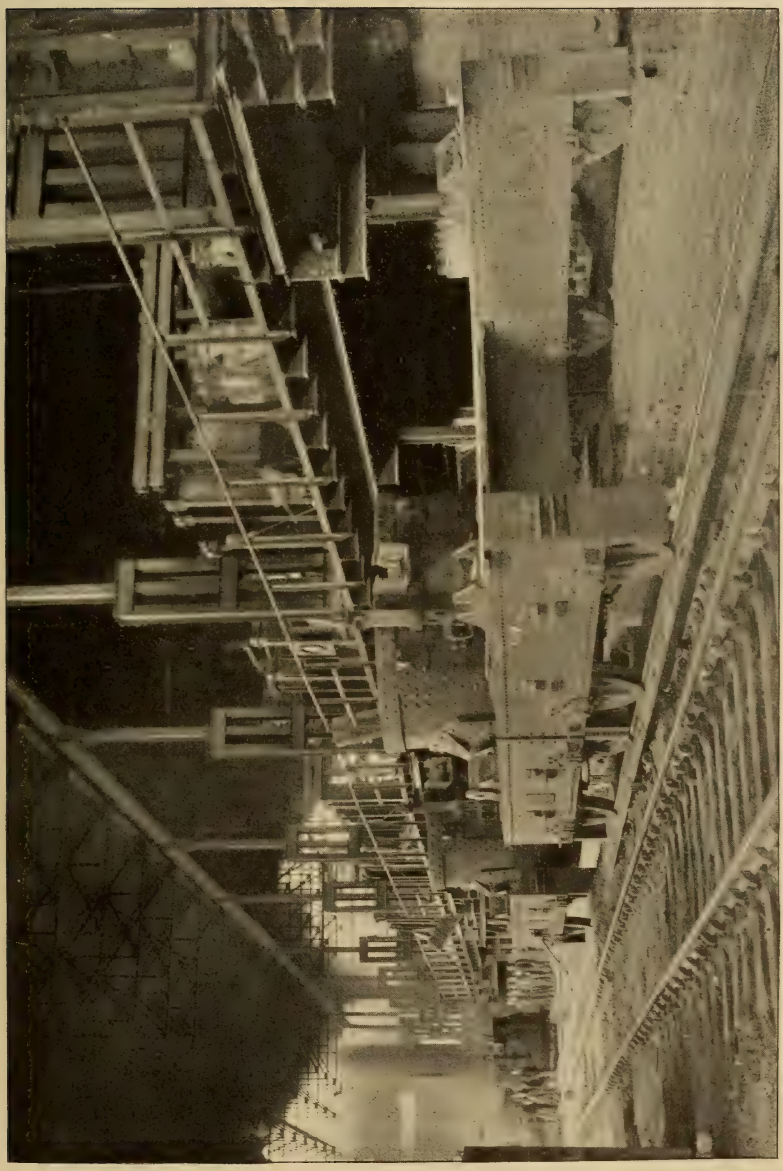
THE story of the development of the steel trade in the North-East of England, and more particularly in the Middlesbrough district, is a most interesting one. Less than a quarter of a century ago that district had little to do with the manufacture of steel, though it was one of the most important finished-iron making centres in the world, and in the zenith of its prosperity so far as regards the value of the iron output, which was as recently as 1873, it had 2136 out of the 7159 puddling furnaces at that time in existence in the United Kingdom. The make of finished iron even twenty years ago was 726,000 tons, but directly after 1882 there commenced a rapid decline, so that in 1900 only 136,000 tons were produced, and in 1901 about 94,000 tons.

This remarkable change has been brought about solely by the supersession of iron by steel, first as a material for use on the permanent way of railways, and afterwards as a material for the construction of both steam and sailing vessels.

It was about the year 1875 that steel began to encroach on the business of the iron-rail makers, and in this district the production of iron rails (which in 1873 was over 374,000 tons, and formed 53 per cent. of its total output of finished iron) had by 1876 dropped to 124,000 tons, owing to the competition of steel. In 1879 the output had dwindled to 8000 tons, or only 2 per cent. of the total production. This decline in the iron-rail trade was a heavy blow to the iron manufacturers of the North of England, which had been the chief seat of that business in Great Britain.

But to counterbalance this falling off there sprang up towards the close of the seventies a vast extension of shipbuilding, so great, in fact, that it required more iron than was necessary to make up for the decline due to the loss of the rail trade; for whereas when the latter was at the height of its prosperity in 1873, the total make of finished iron reached 707,000 tons, in 1882 (the best year for the iron-plate trade) there was an output of 726,000 tons, of which 498,000 tons, or 68 per cent., were in the form of plates, and 150,000 tons, or 21 per cent., in the form of angles, the shipbuilders in the aggregate taking 89 per cent. of the product of the finished-iron works. Now both the iron rail and plate trades are of very little importance.

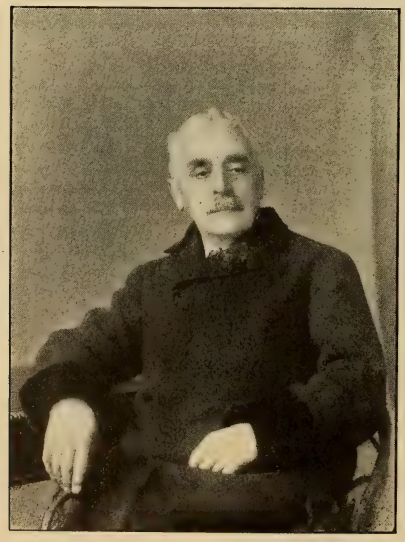
How severely the extension of the steel trade in the district has affected the finished-iron trade will be appreciated when it is stated that out of the forty-five finished-iron manufactories that were in operation in the North-East of England a quarter of a century ago twenty-five have completely disappeared; nine still exist as iron rolling mills; two have added a steel plant to their iron works; six have been converted into steel rolling mills and have abandoned altogether the manufacture of finished iron; two roll steel, but do



IN THE CLARENCE STEEL WORKS OF MESSRS. BELL BROTHERS, LTD.

A VIEW OF THE CONSETT IRON AND STEEL WORKS

not make it; and one is now a foundry. Thus, only twenty of the old works are still in existence. Four entirely new steel rolling mills have been established since 1876, and at the present time twenty-three works are engaged in the North of England in the production of manufactured iron and steel, of which ten are steel works pure and simple. It will be of interest to enumerate the finished-iron works which were in existence in the North-East of England in 1873, just before the commencement of the steel-making era, this information having been officially compiled in that year for the purposes of an arbitration reference. The works that have disappeared are marked with an asterisk: —



SIR DAVID DALE, BART., CHAIRMAN OF THE CONSETT IRON CO., LTD.

MIDDLESBROUGH

*Hopkins, Gilkes & Co., Ltd. (afterwards Tees-side Iron & Engineering Company, Ltd.)
*Bolckow, Vaughan & Co., Iron Rolling Mills.
Britannia Iron Works Company, Ltd. (now Dorman, Long & Co., Ltd.)
West Marsh Iron Co., Ltd. (now Dorman, Long & Co., Ltd.)
Jones Brothers & Co., Ltd., Ayrton Works (now Dorman, Long & Co., Ltd.)
Hill & Ward (now Richard Hill & Company, Ltd.)
Fox, Head & Co. (now John Hill & Co.)
*Erimus Iron Company.
*Eston Grange Iron Company.
*Jackson, Gill & Co., Imperial Iron Works, Southbank.

THORNABY

William Whitwell & Co.
*North Yorkshire Iron Co., Ltd.

STOCKTON

Bowesfield Iron Co., Ltd. (now Bowesfield Steel Company, Ltd.)
*West Stockton Iron Company, Ltd.
*John Holdsworth & Co.
R. Jaques & Co. (now Richmond Iron & Steel Company.)
Johnson & Reay, Moor Works (now South Durham Steel & Iron Company, Ltd.)
Stockton Rail Mill Company, Ltd. (now South Durham Steel & Iron Company, Ltd.)
Stockton Malleable Iron Co., Ltd. (now South Durham Steel & Iron Company, Ltd.)

THE HARTLEPOOLS

*Hartlepool Malleable Iron Company.
*Robert Charlton & Co., Stranton.
*Dunlop, Meredith & Co.
West Hartlepool Iron Co., Ltd. (now South Durham Steel & Iron Co., Ltd.)

DARLINGTON

*Darlington Iron Company, Ltd., Albert Hill.
*Darlington Iron Co., Ltd., Springfield.
*Skerne Iron Works Company, Ltd.
Fry, I'Anson & Co. (now Sir Theodore Fry & Co., Ltd.)
*Thomas Vaughan & Co., Ltd. (Whessoe Works).

BISHOP AUCKLAND

*Thomas Vaughan & Co., Ltd.

WITTON PARK

*Bolckow, Vaughan & Co., Ltd.

TUDHOE

Weardale Coal & Iron Company, Ltd.

CONSETT

Consett Iron Co., Ltd.

SUNDERLAND.

Samuel Tyzack & Co.
*Oswald & Co. (afterwards Wear Rolling Mills Co.)
*Raine Brothers, South Hylton.

FENCE HOUSES

*Hopper & Co.

JARROW

Palmer's Shipbuilding & Iron Company, Ltd.
*John Elliott & Sons.

BIRTLEY

Birtley Iron Company.

GATESHEAD

Thomas Abbot, Teams. (now Redheugh Sheet Iron Company).
Jno. Abbot & Co., Ltd.
*Cook, Hillman & Co.
*Hawks, Crawshay & Co.
*Felling Coal, Iron & Chemical Company, Ltd.

WALKER

*Bell, Ridley & Bell.

The steel rolling mills which have been established are those of Messrs. Bolckow, Vaughan & Co., at Eston; the North-Eastern Steel Company, at Middlesbrough; Messrs. Bell Brothers, Ltd., at Port Clarence; and Messrs. John Spencer & Co., at Newburn-on-Tyne.

Of the iron works in the above-mentioned list, the following have been converted into steel rolling mills and no longer deal with iron:—

Consett Iron Works.
Britannia Iron Works (Dorman, Long & Co.)
Weardale Iron Works.
Palmer's Shipbuilding & Iron Works.
Moor Iron Works (South Durham Steel & Iron Company).
West Marsh Iron Works (Dorman, Long & Co.)

A steel plant has been added to the Stockton Malleable Iron Works, and also at the West Hartlepool Iron Works, and the following works roll steel exclusively:—

Bowesfield Iron Works, Stockton.
Richard Hill & Co., Middlesbrough.

Some of the iron works also roll steel for special customers.

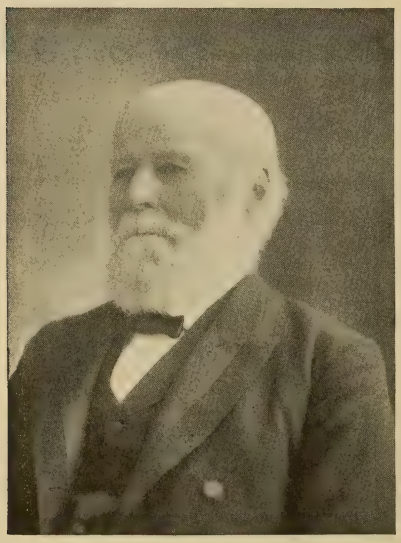
Of the establishments which still remain ironworks the list is as follows:—

Dorman, Long & Co., Ayrton Works.
John Hill & Co., Newport Rolling Mills.

CHARGING PLATFORM FOR THE STEEL FURNACES AT THE CLARENCE STEEL WORKS, PORT CLARENCE

William Whitwell & Co., Thornaby.
Richmond Iron Works, Stockton.
Stockton Rail Mill (South Durham Steel & Iron Company).
Sir Theodore Fry & Co., Rise Carr Rolling Mills, Darlington.
Samuel Tyzack & Co., Sunderland.
John Abbot & Co., Ltd., Gateshead.
Redheugh Sheet Iron Company, Teams, Gateshead.

In 1891 the production of manufactured iron had fallen to 271,000 tons, whereas that of steel ingots had increased to 795,487 tons, which was a greater quantity of material than had ever been made in the best days of the finished-iron industry, and in 1900 the quantity of iron produced was about 136,000 tons, against 1,335,750 tons of steel. As compared with 1891, the



SIR LOWTHIAN BELL, CHAIRMAN OF THE CLARENCE IRON AND STEEL WORKS

make of steel in the North of England in 1900, as ascertained by the British Iron Trade Association, was:—

	1891 Tons.	1900 Tons.
By the Bessemer acid process...	152,748	63,557
By the open hearth acid process..	433,798	978,242
By the Bessemer basic process..	203,461	268,942
By the open hearth basic process.	5,480	25,009
	195,487	1,335,750

The total production of steel in Great Britain by all processes in 1900 was 4,901,054 tons, so that the district under notice made 27 per cent. of the total reported for the whole country, and turned out nearly twice as much steel as it ever did of finished iron.

The iron rails now made reach little more than 1000 tons in the year, and these are for use chiefly in collieries where the dampness of the workings makes it advisable to have iron instead of steel. Iron plates would also long ere this have been ousted by steel, more especially as the latter have for some time been the cheaper,—in fact, considerably the cheaper at times,—but for the fact that the former are less subject to corrosion in positions where protection by paint is not easily maintained. It is very rarely now that an iron ship is built, but there are certain internal parts in steel vessels for which builders and owners prefer to use iron, such as decks, bunkers, engine and boiler seatings, floors, bulkheads and other parts, and thus there is still work for the two iron-platemaking firms remaining in the district. The other finished-iron manufacturers are chiefly occupied in the production of bars which are preferred to steel, especially by the smaller consumers who understand the use of iron better than that of steel, and who consider that it welds better.

EARLY STEEL MAKING

It must not be inferred from the foregoing that the steel trade in the North-East of England was non-existent before 1877; the rolled steel trade practically was non-existent, but the cast steel industry had been carried on to a comparatively small extent. Steel had, indeed, been made in the eighteenth century and was used for the manufacture of edge tools. This was near Shotley Bridge, and not far from the existing works of the Consett Iron Company.

About the year 1810 the manufacture of cast steel by the Huntsman process was introduced into the Tyneside district by Messrs. Crowley, Millington & Co., and also by Messrs. Spencer at the Newburn Steel Works, who were followed by Messrs. Cookson & Co., at Derwent Cote, and Messrs. Fulthorpe & Co., at Dunston. The Uchatius process was also for some time in oper-

ation at Newburn. Up to 1850, however, not more than four firms were engaged in the manufacture of steel on the North-East coast, and they produced nothing but cast steel. In that year Mr. Charles Attwood started the Stanners Close Steel Works, at Wolsingham, to manufacture steel by a process of his own

THE BESSEMER PROCESS FIRST INTRODUCED

The North-East of England can claim the credit of having given one of the first trials to the Bessemer process, for in the year 1856, just after Bessemer had described this process at the Cheltenham meeting of the British Association, Mr. Charles Attwood, who was present at the meeting, was so much impressed by the merits of the invention that he took a license from Bessemer and established steel works in connection with the iron works which he had started at Tudhoe, and the steel plant was laid down partly under the supervision of Bessemer himself. Some of the earliest of the steel ingots turned out at Bessemer's works at Sheffield were sent to Tudhoe to be rolled, and the first ingots made at Tudhoe by the Bessemer process were rolled into rails which were laid down across the High-Level Bridge at Newcastle-on-Tyne. The Bessemer process at Tudhoe, however, has long since been superseded by the Siemens-Martin acid process, though the old Bessemer converters are still standing near the present works.

THN RISE OF THE STEEL RAIL TRADE

For the next twenty years nothing was done in the district in the way of extending the manufacture of steel. No other works were established, and no more Bessemer converters were put up. But shortly before 1876 it was found in other districts that rails could be made by the Bessemer process from hematite pig-iron at a cost which compared favourably with that of the iron rail, and, besides, it was ascertained that the life of the steel rail was considerably longer than that of the iron rail. The economy resulting from the use of the steel rail became patent to railway engineers, and it was soon made clear that they must abandon the use of the iron rail. Orders for iron rails then fell off rapidly, and the rail makers of this district saw their trade quickly leaving them. It thus became necessary for them to put themselves abreast of the times. What the change meant to them may be estimated by the figures given in the opening paragraph of this article.

Soon, however, the North of England from being the largest iron-rail making district became the most important steel-rail making centre in Great Britain. But the change compelled producers to give up the use of pig-iron made from Cleveland ironstone, as it was not adapted for producing steel by the processes then known on account of the excess chiefly of phosphorus and silicon which it contained, and which could not be eliminated at a cost permitting steel rails made from local materials to compete successfully with steel rails produced from foreign hematite ore, which latter began to be imported in large quantities from Spain.

In the best days of the trade in iron rails there were in the North-East of England fourteen works producing them, of which the following were the principal:—

Bolckow, Vaughan & Co.
Consett Iron Company.
Darlington Company.
Johnson & Reay.
Hopkins, Gilkes & Co.
West Hartlepool Iron Works.
Stockton Rail Mill Company.
North Yorkshire Iron Company.
Britannia Iron Company, Middlesbrough.

The last named was founded in 1872 by Sir Bernhard Samuelson. Soon the number of firms producing rails was reduced to three, and now only two establishments roll rails in any considerable quantity, and they are of steel. But these two firms have such large establishments that their total rail-making capacity is equal to over 300,000 tons per annum, or nearly as much as was ever produced of iron rails by the fourteen works of twenty-five or thirty years ago.

The first firm to abandon the iron-rail trade in this district and to start on the manufacture of steel rails were Messrs.

Bolckow, Vaughan & Co., who owned the most extensive and the best ironstone mines in Cleveland. Notwithstanding this, they adopted a course which involved a large reduction in the consumption of their Cleveland ores and necessitated their sending abroad for suitable ores. In 1876, therefore, the directors erected at Eston an entirely new and excellently appointed Bessemer steel rail mill, capable of turning out 4000 tons of rails per week. It was recognised that the position of Teesside was a most favourable one for the manufacture of steel from hematite iron, as, on account of its proximity to the coast and having an admirable waterway therefrom, the steel could be made at a cost as low as that of any competing district, not even excepting Cumberland and Furness, which had within easy reach of the works supplies of native hematite ore, though in recent years this supply has not been adequate, and the North-West of England, like the North-East, has had to import Spanish ore.

Before long the example of Messrs. Bolckow, Vaughan & Co. was followed by the Darlington Iron Company, which had been one of the leading iron-rail making concerns. They also adopted the Bessemer acid process, though not so favourably situated for carrying it on as Messrs. Bolckow, Vaughan & Co.; indeed, ultimately, on account of their inland position, the Darlington Steel Works had to be dismantled, as the iron works before them had been. The company had to convey their hematite pig-iron fifteen miles by rail, and then the finished rails had to be carried a like distance when they were for shipment,—and the bulk of the rail contracts were on export account in more recent years. These extra charges the manufacturers nearer the seaboard escaped, and the Darlington Steel Works, therefore, disappeared in 1896.

THE DEVELOPMENT OF THE BASIC STEEL PROCESS

But the steel makers of the Middlesbrough district could not rest content with producing steel from hematite iron, for which foreign ores were required, and several attempts were made to devise a process by which local ores could be utilised, and that at a cost which would enable the steel to be supplied as cheaply as that produced from hematite iron. Towards one of these endeavours the North-Eastern Railway Company, who, as carriers of the ore, were naturally largely interested, subscribed £20,000. There seemed, indeed, no other course open to the Cleveland ironmasters but to try to deprive their product of the phosphorus which it contained.

To Cleveland fairly belongs the honour of working out to a successful, practical and commercial issue one of the most important methods of producing steel, by which the commoner pig-iron could be utilised. This was what became known as the basic process, and in its development Messrs. Bolckow, Vaughan & Co. were the pioneers, as they had been of the local Bessemer steel trade and also of the Cleveland pig-iron trade. The process was invented, it will be remembered, by Messrs. Sidney Gilchrist Thomas and Percy Carlile Gilchrist. Mr. Thomas, who first suggested it, was not connected with the metallurgical industry in any way, but was an official in one of the London law courts.

The first patent was taken out in November, 1877, and related to a lime lining for the Bessemer converter and to the use of lime in combination with its melted contents. This made it possible to use in the converter pig-iron which contained a large percentage of phosphorus. Experiments were first carried out at Blaenavon, where Mr. Edward P. Martin was manager, and a paper on the subject was prepared for the Paris meeting of the Iron and Steel Institute in the autumn of 1878, but so little importance was attached to it that it was one of the papers which were set aside for want of time. However, Mr. E. Windsor Richards, who was then the general manager of Messrs. Bolckow, Vaughan & Co.'s gigantic undertaking, recognised the importance of the invention, especially to such a firm as his own, who had vast quantities of ore

GAS PRODUCERS AT THE BRITANNIA STEEL WORKS OF MESSRS. DORMAN, LONG & CO., LTD., MIDDLESBROUGH

which they could not use for steel-making purposes. He, therefore, afforded the inventors facilities for carrying on their experiments at the Eston Steel Works.

Many difficulties were encountered, and it was months before the process could be declared a success,—in fact, not till 1880. One of the things which most contributed to this success was the introduction of the "after blow." It was first made at Blaenavon, at the suggestion of Mr. E. P. Martin, the manager, but the inventors did not recognise the value of it and for a long time experimented at Eston in the endeavour to eliminate phosphorus without resorting to that expedient. It was not, however, until after the after blow was made that any satisfactory steel was produced from Cleveland iron.

At first with the basic process a shrunk dolomite (magnesian limestone, a double carbonate of magnesia and lime) was mixed with silicate of soda and water for the lining. This was what Messrs. Thomas and Gilchrist adopted in their original process. Very soon after commencing the experiments at Eston the use of tar as a substitute for the original silicate of soda and water was adopted. This, it appears from the remarks of Mr. E. Windsor Richards at one of the meetings of the Cleveland Institution of Engineers shortly afterwards, was a local suggestion, being made by Mr. John E. Stead, analytical chemist, of Middlesbrough.

In practice it had been found that the lining of the circular converter with any substance containing moisture resulted in the hydration and expansion of the lining, which, in consequence, had a tendency to burst the casing of the vessel, and the lining fell to powder. The substitution of tar free from moisture got over the difficulty, and from that day to this all the dolomite linings have been made with tar. Sir Lowthian Bell, writing on the subject of the basic

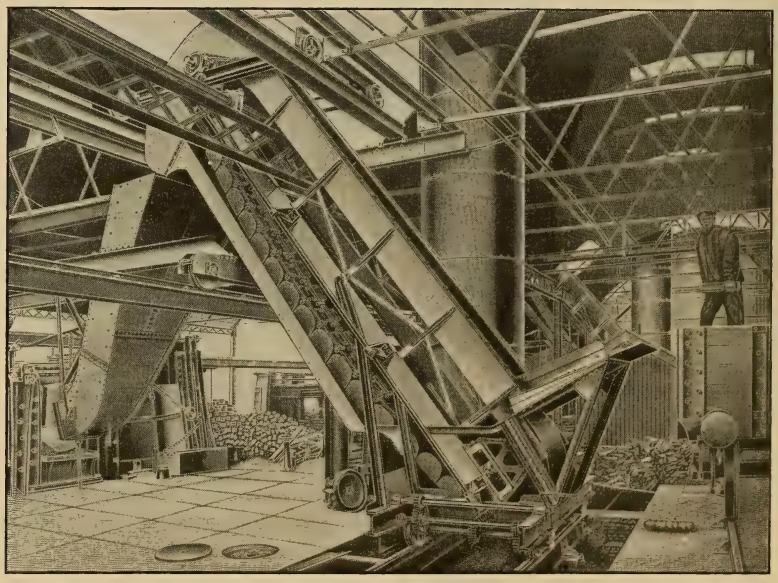
process in his "Principles of the Manufacture of Iron and Steel," remarks:—

"Fortunately, when Messrs. Thomas and Gilchrist brought their ideas before the public Messrs. Bolckow, Vaughan & Co. had just erected a very large steel rail mill on the banks of the Tees, and it was fortunate for the inventors that this work was being carried out under the direction of Mr. Richards. No one who is acquainted with the difficulties that were encountered in the practical application of what may appear a simple matter will deny that to this gentleman and the enterprise and boldness of the directorate merit is due not inferior to that of the originators of the process itself."

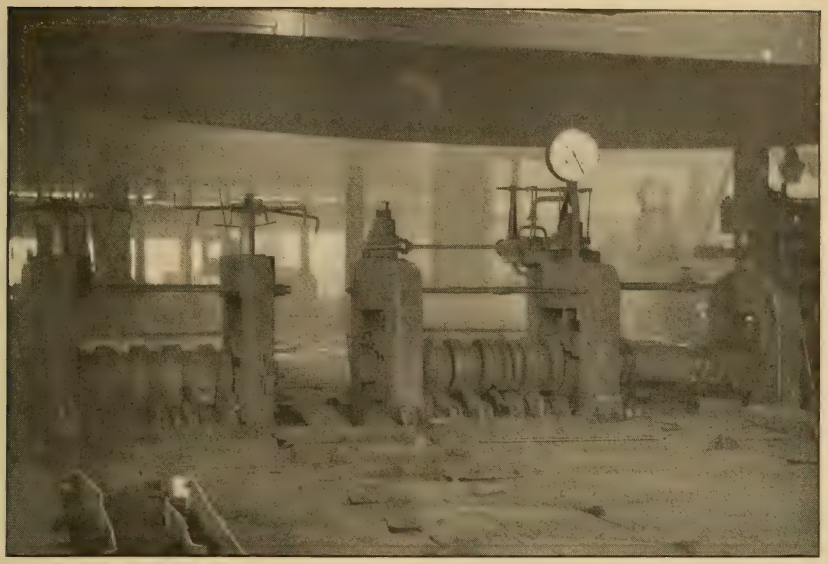
Mr. George J. Snelus, of Workington, it should be mentioned, was associated with the basic process, as he, in 1872, met with a certain amount of success in lining a small converter with lime, and had taken out a patent. In 1880 Messrs. Bolckow, Vaughan & Co. erected an extensive basic establishment adjoining their Bessemer works at Eston, and from Cleveland iron rails of first-class quality were there produced. The Cleveland iron used contained 1.66 to 2 per cent. of phosphorus, and the steel made contained less of it than that produced from hematite iron containing only 0.06 per cent.

EXTENSION OF THE MANUFACTURE OF BASIC STEEL

It is strange that though the basic process was perfected in this district, and had for its object the utilisation specially of the local ores, it has been adopted at only three works in the North of England, namely, at Eston; at the North-Eastern Steel Company's works at Middlesbrough, which were established for the express purpose of working it; and a modification of it at the Clarence Steel Works. It might have been expected that the district which had the credit of making a success of the process, and which possessed such large stores of raw materials that could be utilised, would have been the one to profit most extensively by it. But that has not been the case, for Germany is the chief seat of the manufacture of basic steel, and produces very much more of it than does Great Britain.



A STEEL FURNACE CHARGING MACHINE AT THE MOOR STEEL WORKS AT STOCKTON-ON-TEES OF THE SOUTH DURHAM STEEL AND IRON COMPANY, LTD.



ROLLING MILL FOR TRAM RAILS AT THE ESTON WORKS OF MESSRS. BOLCKOW, VAUGHAN & CO., LTD.

This may be regarded as somewhat anomalous, but the explanation can readily be given. It is that Cleveland is in such a favourable position for importing Spanish ore that it can produce hematite pig-iron very cheaply, and this has led to the development of the acid process of steel-making rather than the basic. Germany, on the other hand, is not so well situated for getting Spanish ore, because the steel works are so far in the interior, and therefore, after being discharged from the seagoing vessels, the ore has to be conveyed from the seaports over long distances by canal or river at considerable extra expense. Thus it has been more to the German manufacturers' advantage to develop the basic process and use their own native ores, which, like the Cleveland ore, are unsuitable for the manufacture of steel by the acid process.

Doubtless as Spanish and other hematite ores get scarcer, it will become necessary to turn more to the utilisation of Cleveland ironstone for steel making purposes. That would be advantageous on several grounds. Great Britain's steel trade would, as it were, be self-contained, and British makers would not have to rely upon any other country for the supply of any materials. Spain, on account of political considerations, is not a country upon which Great Britain can put her trust, and British supplies of ore have before now been interrupted from that quarter.

DEVELOPMENT OF THE STEEL-PLATE TRADE

It has been stated above that the iron-rail industry in the Middlesbrough district, as elsewhere, was superseded by the steel-rail manufacture, but the prestige of the district as a centre for the production of finished iron was not lost when that event occurred, for there rose in the early eighties a vast and unprecedented increase in the demand for new shipping, which called for an immense quantity of iron plates and angles. Shipbuilders at that time looked askance at the use of steel in the building of vessels and preferred to keep to iron, with the virtues of which they were perfectly familiar. So busy did the shipbuilding industry become that in 1882 far more puddled iron was consumed for plates and angles than had ever been used for rails; in fact, in that year the North of England turned out 498,000 tons of plates and 150,000 tons of

angles, or 648,000 tons altogether. Then steel began to compete with iron in the plate trade, just as had been the experience with rails a few years before. Speaking at a meeting of the Institution of Civil Engineers, Sir Lowthian Bell remarked:—

"In its later developments the iron trade in the Cleveland district had many difficulties to encounter. In the first instance the Bessemer process had put an end to the production of iron rails, and scarcely had the iron works recovered from that blow by a great demand fortunately arising for iron shipbuilding when steel again presented itself as a formidable opponent of the trade."

DAVID EVANS, GENERAL MANAGER OF MESSRS. BOLCKOW, VAUGHAN & CO., LTD.

It soon became apparent that little iron would be needed at the shipyards, and some of the manufacturers who could afford it lost no time in altering their establishments so as to satisfy the newer requirements of the shipbuilders Other works gradually dropped out of existence. The type of steel furnace adopted, however, was the Siemens acid, using hematite pig-iron, as shipbuilders preferred to have acid rather than basic steel plates; indeed, those that were produced of the latter description did not then give satisfaction.

Thus, whereas basic steel answered admirably for rails, it did not suit for the manufacture of plates, and this has continued to be the case until within the last two years. While, therefore, the steel rails have been made chiefly by the basic process, plates have been produced altogether by the Siemens acid process. It was held that there was among shipbuilders and also with Lloyd's and the Admiralty a prejudice against basic steel plates, but both Lloyd's and the Admiralty intimated that they were prepared to accept them as freely as they did acid steel if basic steel could be made to fulfil the tests to which acid steel was subjected.

At the autumnal meeting of the Institution of Mechanical Engineers in 1893, Sir William H. White, who was then chief constructor for the British Admiralty, said that "the Admiralty officers had satisfied themselves that by the open-hearth basic process they could get such a material as they could trust. They were not prepared to use basic steel made by the Bessemer process for all purposes in ship work, nor at present to use basic steel made by either process for boiler work; but for ship work they had been prepared for some time past, other things being equal, to use open-hearth basic steel. But other things were found not to be equal; when it came to the test of a contract the basic process had not the relative standing with the acid process that it might be expected to have; in fact, acid open-hearth steel could be bought at a cheaper rate in the quantities required than the basic had ever yet been offered."

On this account Consett, Jarrow, Moor, West Hartlepool, Weardale, The Stockton Malleable Co., Dormans and Eston all have adopted the Siemens acid process for the manufacture of steel plates and angles, and the basic open-hearth furnace has been neglected, until lately a modification of it has been started at the new Clarence Steel Works.

CLEVELAND STEEL AT THE CLARENCE WORKS

Effort to produce steel plates and angles from Cleveland iron as cheaply and of as good quality as those made from hematite iron have, however, not

been wanting of late years. Messrs. Bell Brothers about ten years ago started a manufactory for producing steel by the Pourcel process near their Clarence iron works, and used for the lining of their open hearth furnaces chrome iron ore, but the experiments did not prove successful. M. Pourcel's furnace was the first open-hearth furnace that was erected within the port of Middlesbrough.

The latest attempts to produce steel from Cleveland iron which should be suitable for all purposes have been made by Mr. William H. Panton, one of the managing directors of Messrs. Dorman, Long & Co., Ltd., Britannia and West Marsh Iron and Steel Works, Middlesbrough, who used one of the furnaces at the Britannia Works. The first experiments were in 1894, and the results warranted his pursuing his investigations further. Accordingly, in 1897 he started a furnace at the Roseberry Foundry, Middlesbrough, which was then the property of Messrs. R. P. Dorman & Co., and is now owned by Messrs. Dorman, Long & Co. These experiments were successful, and Sir Lowthian Bell then placed at the disposal of Messrs. Dorman, Long & Co. for further experiments the steel furnaces that had been worked some years before with the Pourcel process referred to above, and they were carried on steadily until it was demonstrated that steel could be made commercially from Cleveland iron which was suitable for all purposes to which steel made from hematite pig-iron is applied. Large steel works have been erected at Port Clarence, and for the present and until the rolling mills there are erected the steel ingots are taken by barge up the river Tees to Messrs. Dorman, Long & Co.'s Britannia Works, and there rolled into girders, angles and other shapes. So far, over 100,000 tons of this steel have been made by the new process, and it has given every satisfaction and stands successfully all the tests to which acid open-hearth steel is subjected.

In the Middlesbrough district, therefore, there are now carried on the Bessemer acid steel-making process at the works of Messrs. Bolckow, Vaughan & Co.; the Bessemer basic at the North-Eastern Steel Works; the Siemens open-hearth acid at all of the plate-making establishments; and a modification of the basic open-hearth at the Clarence Works and Britannia Steel Works.

PIG-IRON MIXERS AT STEEL WORKS

Among the more recent improvements that have been introduced at the steel works in the Teesside district where Cleveland iron is used may be mentioned the mixing and desulphurising apparatus first applied in Germany by Herr Joseph Massenez, of Hoerde. This is employed where the iron is taken direct from the blast furnaces to the steel converters or furnaces, and its advantage is that it secures uniformity in the quality of the steel produced. At present mixers are in operation at Messrs. Bolckow, Vaughan & Co.'s Eston Steel Works; at the North-Eastern Steel Works, Middlesbrough; and at Messrs. Bell Brothers' Clarence Steel Works.

Mixers were first adopted at the Eston Works by Mr. David Evans, the general manager. The two there in operation are each capable of holding 150 tons of pig-iron, and together can deal with the make of four furnaces, or about 2000 tons of iron per week. It is ordinary Cleveland iron that is treated in the mixers, and in them the iron sulphide in the pig-iron is decomposed by the manganese, producing manganese sulphide, which flows off in the slag and leaves the metallic iron free from sulphur. The rails made at Eston by the Bessemer basic process from Cleveland iron so treated are, it is affirmed, practically not to be distinguished from those produced by the Bessemer acid process from Spanish hematite ore.

At the North-Eastern Steel Works the mixer deals with basic iron that is produced at the Acklam blast furnaces, and the steel is rolled into rails, fish-plates, billets, blooms of special mild steel for forgings, etc. The mixer at Messrs. Bell Brothers' Clarence Works

is at present the largest in the world, exceeding even the gigantic apparatus erected at some of the American works. It will deal with 300 tons of pig-iron at a time, the iron being ordinary Cleveland iron produced at the Clarence blast furnaces. In the mixer there the molten metal is heated with gas from three gas producers, and after being thoroughly mixed the metal runs into basic open-hearth furnaces on a lower level.

SOAKING PITS AND VERTICAL INGOT-HEATING FURNACES

Another local invention which was adopted was the Gjers "soaking pits," introduced by Mr. John Gjers, the well-known blast furnace engineer, and one of the founders of the Ayresome Iron Works at Middlesbrough. With this invention the internal heat of the semi-solidified ingots was utilised by placing them vertically in firebrick pits, covered with an iron plate, until an average temperature suitable for rolling was attained. Thus there was no need of putting the ingots into reheating furnaces before rolling. A modification of these soaking pits has been introduced at Eston and also at Messrs. Dorman, Long & Co.'s works. They are known as vertical ingot-heating furnaces and have facilities for heating the charge externally, and, being on the regenerative principle, very high temperatures are attained, with consequently considerable saving of time. Several of the steel works in the district have, however, soaking pits heated by coal with a boiler at the end to take up the spare heat. These are found to answer very well and are slightly more economical on account of the steam that is obtained from the boiler.

SANITER'S DESULPHURISING PROCESS

The process of desulphurising steel which was invented by Mr. E. H. Saniter, of Middlesbrough, now the manager of Messrs. Bell Brothers' new steel works, has been adopted in this district at the Clarence Works, and also at the works of Messrs. Dorman, Long & Co. The process is used mainly in connection with the basic open-hearth furnaces. As at first carried out, Mr. Saniter effected the desulphurisation by introducing into the receiving ladle twenty-five pounds of calcium chloride and an equal proportion of lime per ton of metal. But now the sulphur is removed in the furnace itself by the addition of chloride and fluoride of calcium during the conversion of the molten pig-iron into steel. The adoption of this process has made possible the utilisation of Cleveland and other hitherto non-steel making irons for the production of steel suitable for any purpose.

ELECTRICITY FOR POWER PURPOSES AT STEEL WORKS

All the steel works in the North of England are lighted by electricity; in fact, many have been so lighted for several years, the Eston Works, for instance, for nearly twenty-five; but some steel manufacturers have still further utilised the electric current by applying it as a motive power for, at any rate, part of the machinery at their works. In this district, and, in fact, in Great Britain itself, electricity was first applied for power purposes at the works of Dorman, Long & Co. So satisfactory were the results obtained there that the firm put in a plant at the Britannia Works for generating electricity to drive all the subsidiary machines, which previously had been driven by small steam engines, and the directors have had no reason to regret their enterprise. They bear strong testimony with respect to the economy attained and find electricity to answer very satisfactorily where machinery is scattered over large areas. Now they have 144 motors at work, and adopt electric driving wherever possible; indeed, only the main engines are at present driven by steam. Their electric generators at the Britannia Works consist of three dynamos, each of 160 E. H. P., driven by a Bellis enclosed-type engine and a Mather & Platt dynamo generating 400 E. H. P. driven by a marine-type triple-expansion engine.

At Messrs. Bell Brothers' new steel rolling mills, cranes, live rollers, transfer tables, straightening and ending ma-

chines, etc., will all be driven electrically. There will be also one 100-ton crane so driven. Messrs. Bolckow, Vaughan & Co. are putting down a plant, at a cost of between £60,000 and £70,000, which will enable them to substitute electricity for steam in driving a large part of the machinery at their Eston Steel Works. The plant is being supplied by the Westinghouse Electric Company, of London and Pittsburgh. All the overhead cranes will be electrically driven and also the machinery at the rail bank. Messrs. Palmer's Shipbuilding and Iron Company, at Jarrow-on-Tyne, drive all their outlying machinery by electricity.

CHARGING APPARATUS FOR STEEL FURNACES

An apparatus is in use at the South Durham Steel and Iron Company's Moor Works, Stockton, which deserves attention. It is the invention of Mr. Henry Tomkins, the steel works manager, and is for charging the open-hearth steel furnaces. It has been worked so successfully there for three years that the firm have erected eight additional machines,—one for each of their furnaces. As compared with charging the furnaces by hand there is a saving on the make of plates of at least 1s. per ton. By hand labour the time required to charge from forty to fifty tons of pig-iron and scrap is from four to five hours, five men being employed. The adoption of these machines enabled the firm to increase their output of ingots 12½ per cent., besides dispensing with the third hand at the furnaces and also the pig wheelers.

The machine is essentially composed of a hollow shaft or chute with an elevator or overhead railway for feeding the material directly into the chute, through which it passes by gravity into the furnace. In its simplest form the chute is mounted on two girders. These are fixed upon an overhead travelling crane arrangement which allows the chute to be carried along from one charging door to another, if required. The chute may be mounted on trunnions so that it can be drawn back when passing furnace doors, or be projected into the furnace when necessary. It is built up of steel plates, a double thickness of plates being used, so that the inner plate can be changed when worn out. A layer of asbestos is placed between the plates composing the chute, as a means of deadening the noise made by the falling materials and also helping to keep the chute cool.

The girder frame for carrying the chute is mounted on two bogeys, running on rails which are supported by girders carried on brackets attached to the roof columns. An elevator of the endless type is provided, with buckets driven from an overhead shaft. It may be either fixed or mounted on a travelling bogey, with its lower end mounted on a bogey winch and its upper end on an overhead travelling bogey. To the bottom bogey and at a convenient height for delivering the pigs from the railway trucks is placed a loading table made of iron plates carried on angle frames. This is so arranged that the pigs drop over the edge of this plate into the elevator buckets at a point slightly higher than the trailing shaft. The elevator buckets are made of steel plates with angles riveted to the bottoms to secure them to cast-steel links.

There are three cast-steel link chains. The loading table at the bottom of the elevator projects out about 5 feet and within 6 inches of the railway waggon. The material is thrown direct from the truck on to it and slides into the buckets. Sometimes as many as five or six men are employed on a truck, and they are all throwing out the metal and scrap together, the elevator conveying the material in an endless stream to the top of the chute, from which it is ejected in a continuous stream into the furnace. The material slides down the chute and finally takes a curve and is deflected at the bottom being carried right across the furnace hearth. The height of fall from the top shaft of the elevator to the floor of the steel furnace is about 22 feet. This gives sufficient force to carry the pig-iron right across the furnace, on to the opposite side, but the force is not sufficient to damage the furnace bottom.

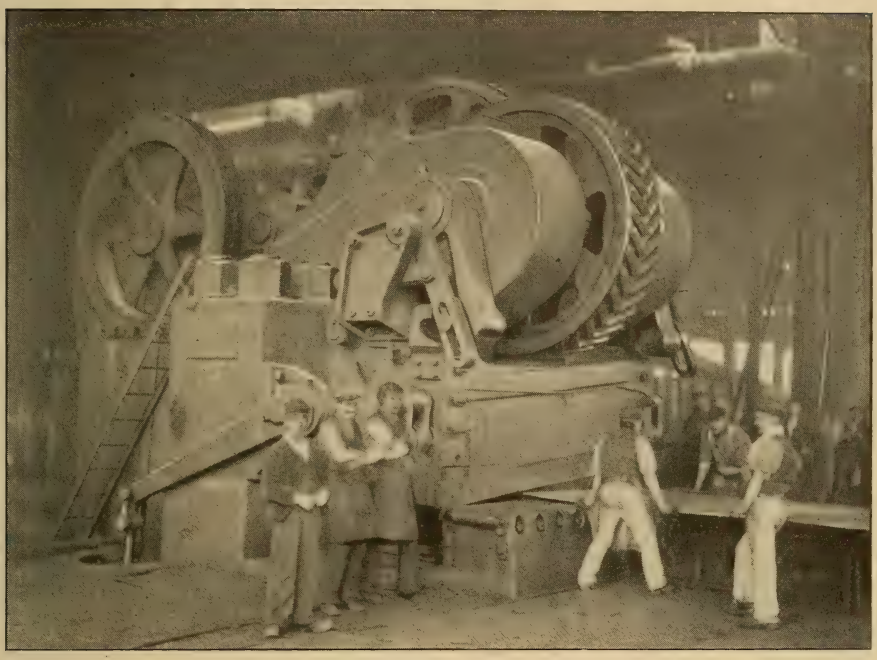
Where the form of ground will permit, an elevated railway instead of an elevator may be used, the trucks being brought alongside the chute and the pig-iron and scrap being thrown direct into it. The time required for repairs is not more than if the furnaces were charged by hand. The adoption of the charging apparatus at the Moor Works has enabled the company at their eight furnaces to dispense with thirty-two men, of whom sixteen were well-paid ones. It is intended to put down these machines also at the firm's Stockton Malleable and West Hartlepool Steel Works.

THE WEARDALE GAS FURNACE FOR REHEATING STEEL SLABS

Attention may be drawn to a new type of reheating furnace which has been introduced at the Weardale Steel Works, Tudhoe, and is the invention of Mr. Henry W. Hollis, lately the general manager, and now director, of the Weardale Steel, Coal and Coke Company. Such satisfactory results have there been attained with it that similar furnaces are being adopted not only in Great Britain, but also abroad, including Germany, Italy and Spain. By the use of this furnace it is claimed that the steel-plate maker can in fuel alone save 2s. 2d. per ton of finished plates.

The principle of Mr. Hollis's furnace is the introduction of a gas flame through, and surrounded by, a stratum of highly heated air in the roof of the furnace, the flame pouring down upon the slabs or piles to be heated and passing along the floor of the working chamber to an outlet port. Equal heating over the whole floor of the chamber is obtained. One object of the designer was to dispense with the regenerating chambers altogether on account of their cost. When he got his invention through the experimental stage at Tudhoe, two large furnaces were erected, the heating chamber of the smaller one being 30 feet long from end to end and 7 feet wide from front to back; the larger had a heating chamber 34 feet 6 inches by 11 feet, the great width being designed to take in the 6-ton and 7-ton slabs rolled in the large mill at the works. The larger of the furnaces can heat thirty-six 5-ton slabs,—180 tons; and the smaller, thirty-six 70-cwt. slabs,—126 tons, together 306 tons per shift. Of smaller

STEEL FURNACES AT THE WEARDALE WORKS



GIANT SHEARS AT MESSRS. BOLCKOW, VAUGHAN & CO.'S WORKS

slabs, say, 30 cwts., each furnace can heat from 60 to 90 tons, or, for both furnaces, say, 180 tons per shift.

The furnace doors are not lifted by counterpoised levers in the usual way, but each door is coupled to the cross-head of a small hydraulic piston moving in a cylinder bolted to a cast-iron plate above the door. Half-inch pipes take the water to and from the cylinders, and a boy who sits in view of the chief furnaceman raises and lowers each door as required.

One advantage which is worth particular notice is that when the slabs have attained rolling heat they can be kept at that temperature, if required, for several hours without appreciable waste or any danger of "burning" by simply closing the air slides,—an extremely useful feature in the event of any interruption in the regular running of the mill. The trouble, delay and cost of withdrawing and replacing the slabs with which the furnaces have been charged is thus avoided. When work is resumed, the slabs can be ready for rolling in a few minutes, and will behave in the mill as though there had been no stoppage.

In the Weardale furnace the working is continuous, charging going on at one door at the same time that slabs are being withdrawn at another, and the furnace is never empty. At a Hollis furnace, with a hearth 39 feet 6 inches by 7 feet, over a period the average weight of slabs heated per shift was over 122 tons, and the coal consumption at the producers was 10 tons 8¾ cwts. Thus 1.708 cwts. of coal were used per ton of slabs heated, and 150 tons per shift might have been heated if large plates were to have been rolled. The furnace is also employed for heating boiler plates for flanging or dishing press, for heating forgings for hammers and other special purposes.

IMPROVEMENTS IN ROLLING MILL MACHINERY

The steam hammer, which was so necessary a part of the equipment of finished-iron rolling mills, has disappeared from the steel works, though up to about the year 1887 it was the regular

custom to hammer steel ingots. Instead of the hammer there is now the cogging mill. But it was a considerable time before it was admitted that cogged steel ingots would produce plates as reliable as those which had been hammered. The addition of the cogging mills has enabled plate makers to increase the output of their mills very materially and also to improve the quality of the plates produced. Any hammering that is now carried on is in the manufacture of forgings, and the leading producers of these have substituted hydraulic forging presses. Cogging and finishing at the mills are now done by powerful reversing engines, which, in the cogging of plate mills, are always geared, but in the rail finishing mills they are worked direct. Reversing rolling mill engines in this district are neither compound nor condensing, as manufacturers consider that all rolling mill machinery should be as simple as possible.

THE TALBOT PROCESS

The Talbot continuous steel process has not yet been started at any of the works in the North-East of England, but licenses have been taken by the Weardale Steel, Coal and Coke Company and the South Durham Steel and Iron Company, Ltd.

GAS PRODUCERS

At the various steel works the gas for the melting furnaces is made in gas producers of the Siemens, Wilson or Dawson type, and these are in most cases fitted with automatic hoppers so that they are self-feeding.

UTILISATION OF BASIC SLAG FROM STEEL CONVERTERS

At Messrs. Bolckow, Vaughan & Co.'s Eston Steel Works, and also at the North-Eastern Steel Company's works, where the Bessemer basic process is carried on, the slag from the converters is utilised for the manufacture of fertilisers, owing to the large percentage of phosphorus which it contains. Special works have been put down near these steel works by a separate company, first known as Messrs. H. & E. Albert, now as the Chemical Works, Ltd. The fertiliser produced contains from 17 to 20 per cent. of phosphoric acid, 50 per cent. of lime and 14 per cent. of iron oxides, with smaller quantities of other ingredients. It is largely used both at home and abroad.

STEAM PRESSURE AND BOILERS

At the steel works Lancashire boilers are now generally employed, and the pressure of steam, which used to be 35 to 60 pounds per square inch in the finished-iron works, is now increased to 80 or 100 pounds. Coal is fed, in most cases, by mechanical stokers.

STEEL FOUNDRIES

A record of the extension of the steel trade in this district would be incomplete without mention of the works which have been established for the production of steel castings. Among these are,—

The Darlington Forge Company, Ltd., Darlington.
John Spencer & Sons, Newburn-on-Tyne.
John Rogerson & Co., Wolsingham.
William Shaw & Co., Middlesbrough.
Ridley & Co., Swalwell.
Blackett, Hutton & Co., Guisbrough.
Alliance Cast Steel Foundry Co., Southbank.

Steel castings are made both by the Siemens-Martin and crucible processes, and they include propeller blades, dredger buckets, anchors, stern and rudder posts, crankshafts, waggon and locomotive wheels, etc. The works of Messrs. John Rogerson & Co., at Wolsingham, have been established a good many years, the founder being the late Mr. Charles Attwood.

The Wellington Steel Foundry, at Middlesbrough, was founded in 1889 by the late Mr. William Shaw, who had been for many years manager at Wolsingham.

THE LEADING STEEL WORKS

The following information respecting the leading steel works will be of interest:—

Messrs. Bolckow, Vaughan & Co.'s Eston Works.—This firm was the pioneer of the steel trade of Teesside, as it had been of the pig-iron and also the finished-iron manufacture. They started Bessemer steel works at Eston in 1876;

a Bessemer basic plant was added in 1880, and afterwards an open-hearth acid steel plant. They have now ten Bessemer converters, of which six are of 8-ton and four of 12-ton capacity. The open-hearth plant consists of ten furnaces of an average capacity of 30 tons. One furnace has a capacity of 45 tons, and two more are to be added,—each with a capacity of 50 tons. The company will then be able to produce 2800 tons of open-hearth ingots per week. The total capacity of the Eston Steel Works is 8500 tons of Bessemer and open-hearth steel ingots per week, the finished capacity being 3000 tons of heavy rails, girder and tram rails; 1500 tons of ship plates; 500 tons of railway sleepers; and 200 tons of small sections, fish, rounds, squares, etc.,—total, 5200 tons.

Two sets of gas producers supply the heat to the open-hearth furnaces, one set of the Siemens type and the other of the Dowson system, the latter fitted with automatic hoppers. When laid down in 1876, the steel works were contained under eight spans, each 64 feet wide and 30 feet high, but they have been so much extended that now they require fourteen spans to cover them. About three years ago the firm laid down a new mill for the manufacture of steel girder tram rails, of which they make a specialty. They can roll up to 60-foot lengths and to any weight of section per yard. They have already executed large contracts for many of the corporations in Great Britain, among them Manchester, Glasgow, Brighton, Birkenhead, Cardiff and Nottingham, and also the London United Tramways at London, Bristol and Middlesbrough.

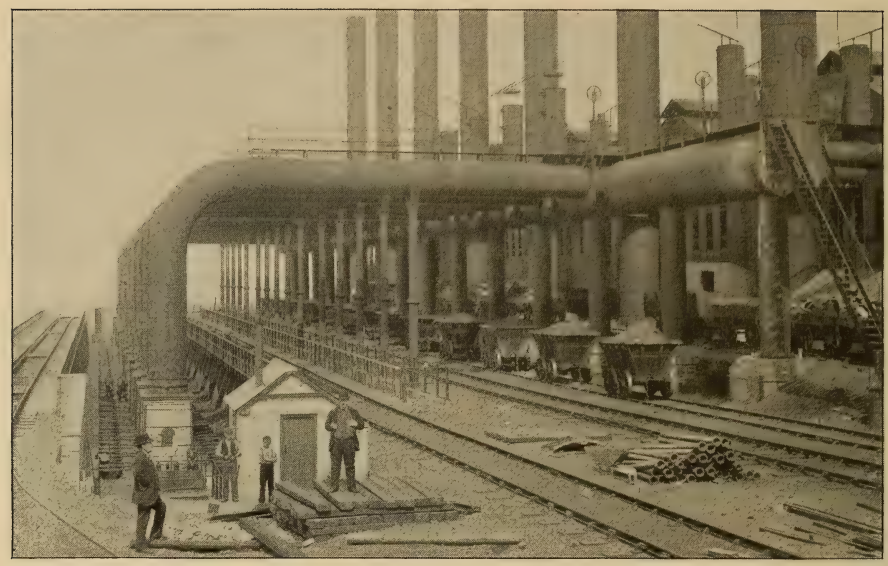
The Clarence Steel Works.—The most recently established steel works are those of Messrs. Bell Brothers, Ltd., at Port Clarence. Several years ago experimental works were put up for operating with the Pourcel process, but this process was not a success, and the works were idle for a long period, when, in 1899, it being found that steel could be made from Cleveland iron profitably, a regular plant was put down, and at present there are four Siemens-Martin basic furnaces, each having a capacity of 45 tons, which are fed with molten iron from the mixer by a ladle containing 25 tons. Other furnaces are now in course of erection. This iron, on arriving at the front of the steel furnaces, is lifted on hydraulic tables and poured into the furnaces by hydraulic cylinders. In this way the ladle is never suspended, and the chance of accident is much reduced.

The rolling mills are not yet ready, but when they are the ingots will be placed in soaking pits and afterwards taken to the mills. These will consist of three stands of three-high rolls, 32 inches in diameter, driven by a vertical compound condensing engine. A 100-ton, electrically-driven, overhead crane will be provided, capable of lifting a pair of standards and set of rolls complete, so that the mill can be rapidly changed to roll various sections.

The blooms will be cut to the required lengths by a pair of specially designed hydraulic shears, and then go on to electrically driven transfer tables, which will move them to each pass in the rolls. When the finished bar is rolled, it will be taken by live rollers, also electrically driven, to the hot saws. There will be two "hot banks." Two overhead gantries will be provided with electric cranes, which will take the bars from the hot bank to the straightening and ending machines, all of which will be electrically driven. Rapid progress is now being made in the laying down of these rolling mills.

Messrs. Dorman, Long & Co.'s Works, Middlesbrough.—Messrs. Dorman, Long & Co., Ltd., commenced the manufacture of steel in 1886 at the Britannia Iron Works, which had been established in 1872, with 120 puddling furnaces, as an iron-rail mill by Sir Bernhard Samuelson, Bart. In 1886 half the puddling furnaces were pulled down and seven Siemens-Martin open-hearth steel furnaces were erected in their place. Subsequently the whole of the puddling furnaces were pulled down and replaced by steel furnaces. These now number eleven.

This firm makes a specialty of the



GAS PRODUCERS AT THE CONSETT IRON AND STEEL WORKS

production of steel girders. In 1883 they started the manufacture of iron girders at the Britannia Works. Up to that time girders had largely been made in Belgium and Germany. The firm, however, have given up the production of iron girders, and now are the largest makers of steel girders in Great Britain. Almost all are produced from steel made from ordinary Cleveland iron.

Messrs. Dorman, Long & Co. have now practically ceased the manufacture of iron at their West Marsh Iron Works, and produce steel instead. The Cleveland steel rolled at these works is produced partly there and partly at the Clarence Works. For the manufacture of structural steel work they have erected extensive shops and employ a large staff of men in drilling, cutting and riveting up the girders to required forms. Columns and stanchions which used to be made of cast iron are now almost exclusively of steel, being chiefly formed of rolled girders. In 1900 nearly 30,000 tons of structural steel work were turned out at the Britannia Works, and 600 men were employed in that branch alone of the company's operations. At the company's Ayrton Rolling Mills 400 tons of iron and steel sheets per week are produced, the bulk of which are galvanised and corrugated. Altogether, Messrs. Dorman, Long & Co. employ 3000 men, and turn out about 3500 tons of finished material weekly.

The North-Eastern Steel Works, Middlesbrough.—These works are worthy of note, as the company establishing them was projected by the patentees of the basic steel process,—the late Mr. Sidney Gilchrist Thomas and Mr. Percy C. Gilchrist, who were joined by Mr. R. C. Denton, the present chairman, Sir Thomas Wrightson, M. P., and Mr. A. J. Dorman. The works were designed and laid down by the present managing director, Mr. Arthur Cooper, in 1881-2, and have since been largely extended. The North-Eastern Steel Company, Ltd., have acquired the blast furnace plant at the Acklam Iron Works, adjoining their steel works, and now they make most of the basic pig-iron which they use. They have recently reconstructed this blast furnace plant, and the four large furnaces are now on the most modern lines and are supplied with blast by some of the finest blowing engines yet built.

The basic iron from these furnaces, which is made chiefly from Cleveland ores, is now taken in a molten state to the mixer at the steel works. The company have adopted the latest plan of making their coke close to the blast furnaces into which it is charged, and have put down a battery of Semet-Solvay ovens complete with a by-product recovery plant.

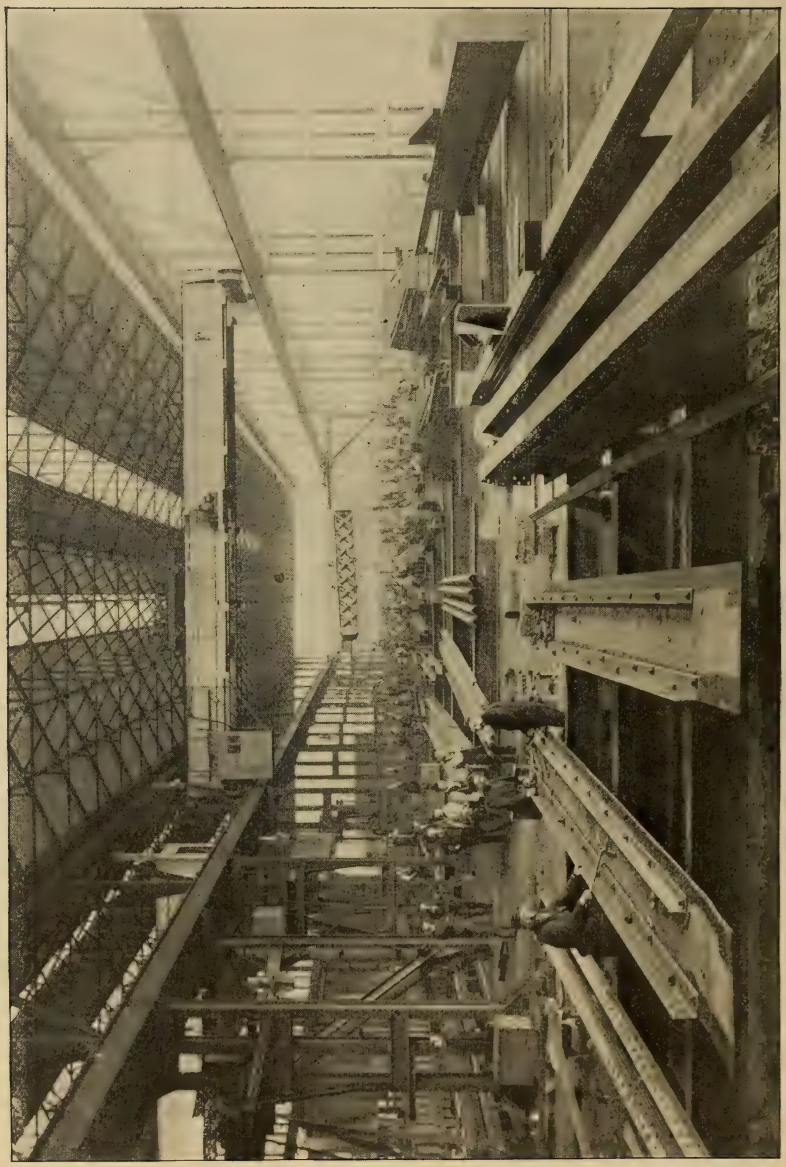
The steel works plant consists of four 10-ton converters, all working by means of transfer cranes into one casting pit. The production of the works is about 3500 tons of finished material weekly in the shape of rails and fish-plates, billets, blooms of special mild steel for forgings, slabs, tin bars, etc. A very large business in rails is done with Norway, Sweden, the British colonies and India, in addition to the home railways. It may be mentioned that the company are just completing an entirely new and extensive plant embodying all the latest and best ideas of modern rolling mill practice for the production of girder rails for electric tramways. Many of the machines in this department are of new and special design for the work mentioned. In this mill rolled joists, channels and all structural sections will be produced, and the total output will, it is expected, reach 4000 tons per week. The works of the company, which originally covered twenty-two acres, now extend to seventy acres, and are well situated close to the river Tees.

The South Durham Steel and Iron Company's Works.—About three years ago the businesses of the Moor Steel and Iron Company, Ltd., of Stockton; the Stockton Malleable Iron Company, of Stockton; and the West Hartlepool Steel and Iron Company, Ltd., of West Hartlepool, were amalgamated under the style of the South Durham Steel and Iron Co., Ltd., with Sir Christopher Furness as chairman and Mr. Charles J. Bagley as managing director. The works of these three companies had existed as finished-iron manufactories for a good many years, but had been converted into steel works,—the Moor in 1885, the West Hartlepool in 1888, and the Malleable in 1889,—and now at the three works there are twenty-three Siemens acid furnaces of from 45 to 50 tons capacity, capable of producing 7000 tons of ingots per week, representing over 5000 tons of plates and sheets. At West Hartlepool, however, iron plates and sheets are still made, but only in small quantities, and at the Stockton Malleable Works 500 tons per week of iron angles and sections are produced.

The three works cover about 200 acres of land, and at the Stockton Malleable Works there are two excellent wharves which give the company good facilities for receiving their pig-iron by water and for shipping their plates. All the works are, however, within 1s. carriage by rail of the blast furnaces. At the Moor Works, as has been stated previously, there are eight mechanical charging machines for the steel furnaces, and a three-high plate mill which is worth notice. It is, in fact, the only one of the sort at present in the district, and is capable of rolling 1000 tons of plates per week. At the Stockton Malleable Works the Perrins process for manufacturing iron and steel tubes has

CHARLES J. BAGLEY, MANAGING DIRECTOR OF THE SOUTH DURHAM STEEL AND IRON COMPANY, LTD.

been introduced, and is giving such good results that the plant is to be extended, so as to practically double the present output. At the West Hartlepool Works the production of steel has recently been doubled.



THE GIRDER SHOP AT THE BRITANNIA STEEL WORKS MIDDLESBROUGH

Consett Iron and Steel Works.—The Consett Iron Company, Ltd., were among the largest producers of iron rails and plates in Great Britain, but after 1876, when steel rails began to be substituted for iron, they directed their attention to the enormous and unparalleled demand for iron plates which sprang up, and did not enter upon the manufacture of steel rails. Their rail mills were demolished and rails have never since formed any part of the production at the Consett Works.

In 1883, when it became evident that steel was superseding iron for shipbuilding purposes, the company, being determined to keep abreast of the times, started two 13-ton Siemens furnaces, with an 8-ton steam hammer and a Siemens furnace for heating the ingots, and the manufacture of steel plates from hammered ingots was commenced. Soon afterwards six 17-ton furnaces were erected and the use of the hammer was discontinued, cogging being substituted. In 1887 another plant of nine 25-ton melting furnaces was put down, and the ingot-producing capacity of the two plants was then above 3500 tons per week. In 1888 the company extended their works so as to supply the shipbuilders with angles and other sectional steel. The new mills consisted of fifteen blocks of gas producers, seven melting furnaces, a 45-inch cogging mill and bloom cutting shears, and three mills for the production of angles, tees, bulbs, channel and girder sections, and round and square bars, the plant being capable of producing 1500 tons of angles, bars, etc., per week. The Consett Iron Company no longer produce any finished iron and their steel is all manufactured by the Siemens acid process. Their weekly output of steel plates is 2500 tons, and of steel angles, tees, bulbs, z bars, channels, bulb tees, and round, square and flat bars, etc., 1800 tons.

The Weardale Steel Works.—These were established in 1853 as iron works by Mr. Charles Attwood, of Wolsingham, and here were laid down some of the earliest Bessemer converters ever started, Mr. Attwood having been among the first to appreciate the importance of Bessemer's process.

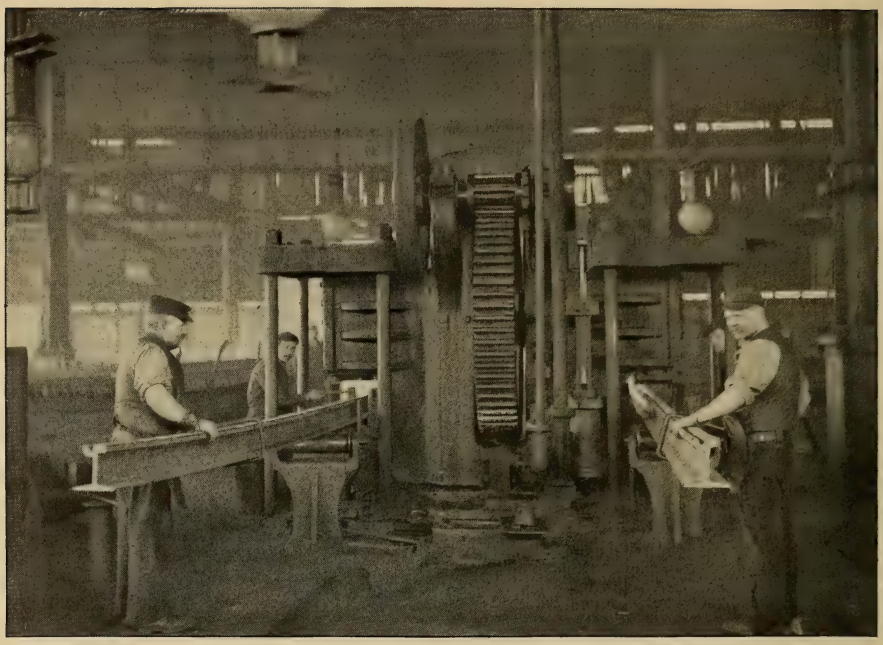
Afterwards the Bessemer process was abandoned and the directors devoted their attention to the manufacture of finished iron. About twenty years ago they started the Siemens-Martin process of steel making. In 1892 they laid down a new cogging mill and afterwards two plate mills, one of the latter being the largest in Europe, if not in the world, capable of rolling plates up to 13 feet in width. Towards the end of 1901 the Tudhoe Steel Works

ARTHUR COOPER, MANAGING DIRECTOR OF THE NORTH-EASTERN STEEL COMPANY, LTD., MIDDLESBROUGH

PHOTO BY THE LONDON STEREOSCOPIC CO.

were stopped, and the men, to the number of 1100, paid off. Nothing official has yet been made known of the intentions of the directors as to the future of the works.

Palmer's Steel Works, Jarrow-on-Tyne.—The Jarrow Works were started by Mr. (now Sir) Charles M. Palmer and his brother, George, as a shipyard, and afterwards engine works, blast furnaces, iron rolling mills and steel works were added, until now the works cover an area of 100 acres, and have a river frontage of nearly three-quarters of a mile. They include within themselves



A TRAM RAIL STRAIGHTENING MACHINE AT MESSRS. BOLCKOW, VAUGHAN & CO.'S ESTON WORKS

the entire range of operations, from the smelting of ore to the complete equipment of the vessel. The company have their own iron ore mines both in Cleveland and Spain.

In the steel works there are eight melting furnaces, each of 40 tons capacity, and in them the hematite pig-iron is converted into Siemens-Martin mild steel by the acid process. In the rolling department there are two 38-inch cogging mills, one of which cogs for plates and the other for sectional material. There is a 36-inch sectional mill, driven by a pair of 50-inch reversing engines, in which all kinds of sections used in ship and bridge building are rolled. A 20-inch and a 12-inch mill roll smaller sections and rounds and squares. The plate mill has rolls 30 inches in diameter by 8 feet long, and the average production is 1000 tons per week. The sheet mill has rolls 22 inches in diameter by 5 feet long, and is chiefly used for the rolling of material employed in the construction of torpedo-boats. There is a complete installation of electric power for driving all the outlying machinery. The company have a powerful plate-ripping and edge-planing machine, which will deal with plates up to 6 inches thick. There is also a complete plant for cambering and welding the knees on ships' deck beams.

COPPER IN THE UNITED STATES

By J. Parke Channing.

A GLIMPSE OF LAKE SUPERIOR

TO the mining engineer, one of the most interesting districts in the United States is that which geologically bounds the edges of that great inland sea, Lake Superior. Although the rocks containing the copper are found all around the rim of the basin, yet the productive part is confined to that finger-line peninsula, Keweenaw Point, and its base, the Ontonogan district.

To one who is accustomed to expect valuable metals hidden in dingy-looking ores, it is a surprise to find in the Lake Superior district the copper in the rock standing forth bright and clean, as if it had just come from the hand of some ancient coppersmith. And, indeed, the present generation is not the first which has exploited this district. Indications point to the fact that long before the time of Columbus, of the Norsemen, or even before the supposed invasion of the Mongols, an ancient race laboriously beat chunks of copper from the Lake Superior rocks and carried them as far south as Mexico.

The rocks of the Lake Superior copper district are interbedded volcanics and sediments. These dip at an angle of from 15° to 60° from the horizontal, the average dip in Houghton County being about 45°. The copper occurs in both the volcanic and in the sedimentary rocks in the form of masses and particles varying in size from those tons in weight down to an impalpable powder.

The veins, or "lodes," as they are locally called, are either the vesicular tops of the volcanic beds known as amygdaloids, or else the conglomerates. In width they vary from 3 or 4 feet up to 30 feet. The principal mine of the district is the famous Calumet & Hecla. This property operates a conglomerate, known as the "Calumet Conglomerate," which averages about 14 feet in thickness and dips to the northwest at an angle of 38 degrees. It is opened up for a distance of at least 10,000 feet on the strike by twelve shafts in the lode, some of which are over a mile in depth. In addition to this, it has one vertical, six compartment shaft, which, up to a short time ago, had the distinction of being the deepest in the world, —about 4900 feet. The Tamarack Mine also works on this same bed of conglomerate, having access to the lode by five vertical shafts, the deepest one, No. 5, having intersected the lode last year at a depth of 4662 feet from the surface. It is now over 5000 feet deep.

The depth to which many of the Lake Superior copper mine shafts have

A VIEW OF THE FAMOUS CALUMET & HECLA MINE DISTRICT, SHOWING SHAFT HOUSES AND MINERS' HOMES

reached has brought up many new and interesting problems in the way of hoisting, the solutions varying from the tail rope system at the Red Jacket shaft of the Calumet & Hecla, to the double-cone drum with four cylinders at the No. 5 shaft of the Tamarack Mine. In addition to these, enormous cylindrical drums, 30 feet in diameter, and with cylinders 42 × 84 inches, may be found at the Quincy Mine, as well as at the Tamarack. These larger hoisting engines all have a capacity of at least 7000 feet of rope.

SHAFT ROCK HOUSE AT THE TAMARACK MINE, CALUMET, MICHIGAN

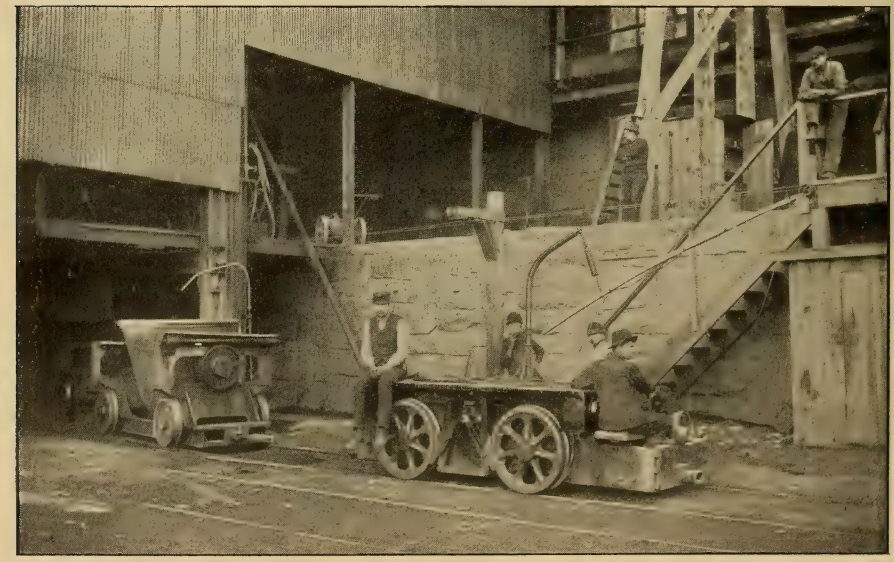
The mining is done by overhead or breast stoping, the levels usually being 100 feet apart. The rock is loaded into cars having a capacity of about two and one-half tons, and is in these hauled to the various shafts, where it is hoisted to the surface in self-dumping skips, holding, as a rule, five tons of rock. In the vertical shafts the skips, so far, have not been a success, and three-ton cars are run upon the cages and hauled up.

At the head of each shaft is located a crushing plant, the combined head frame and crusher building being locally known as a "shaft rock house." Here the rock is crushed to a size not to exceed 5 or 6 inches in its largest dimension, and at those mines containing much mass copper the coarse stuff is picked out after having been loosened by a steam hammer. Most of the rock mined to-day, however, is what is known as "stamp" rock, and but few masses are found, except at the Quincy Mine.

In all the work compressed air is used for operating the rock drills and the pumps, and for running the small underground hoists which handle rock from the winzes and timber in the stopes. Some of the newest compressors in service have a capacity of from fifty to seventy-five air drills, and have triple-expansion steam ends and three-stage air ends with two intercoolers, all the air valves being mechanically operated.

From the shaft rock houses railways convey the rock to the stamp mills, which are located either on the shores of Lake Superior or on the two connecting bodies of water, Torch Lake

LADLE CARS MADE FOR THE ANACONDA COPPER MINING COMPANY BY THE AMERICAN ENGINEERING WORKS, CHICAGO, ILL.



A BALDWIN-WESTINGHOUSE ELECTRIC DOUBLE-TROLLEY LOCOMOTIVE HANDLING SLAG POTS AT THE WORKS OF THE TENNESSEE COPPER CO., COPPER HILL, TENN.

and Portage Lake. These mills, differing from the usual gold mills, are provided with very large steam stamps operated by high-pressure steam, and run condensing. The capacity of each stamp varies from 300 to 500 tons of rock a day, the material being crushed through screens having from 3-16-inch to ½-inch openings.

Systems of hydraulic separators, jigs, tables, vanners, and regrinders complete the mill, and a product is produced and the Calumet & Hecla not exceeding sixty pounds, or 3 per cent. About one-quarter of the copper contained in the original rock is lost in the tailings.

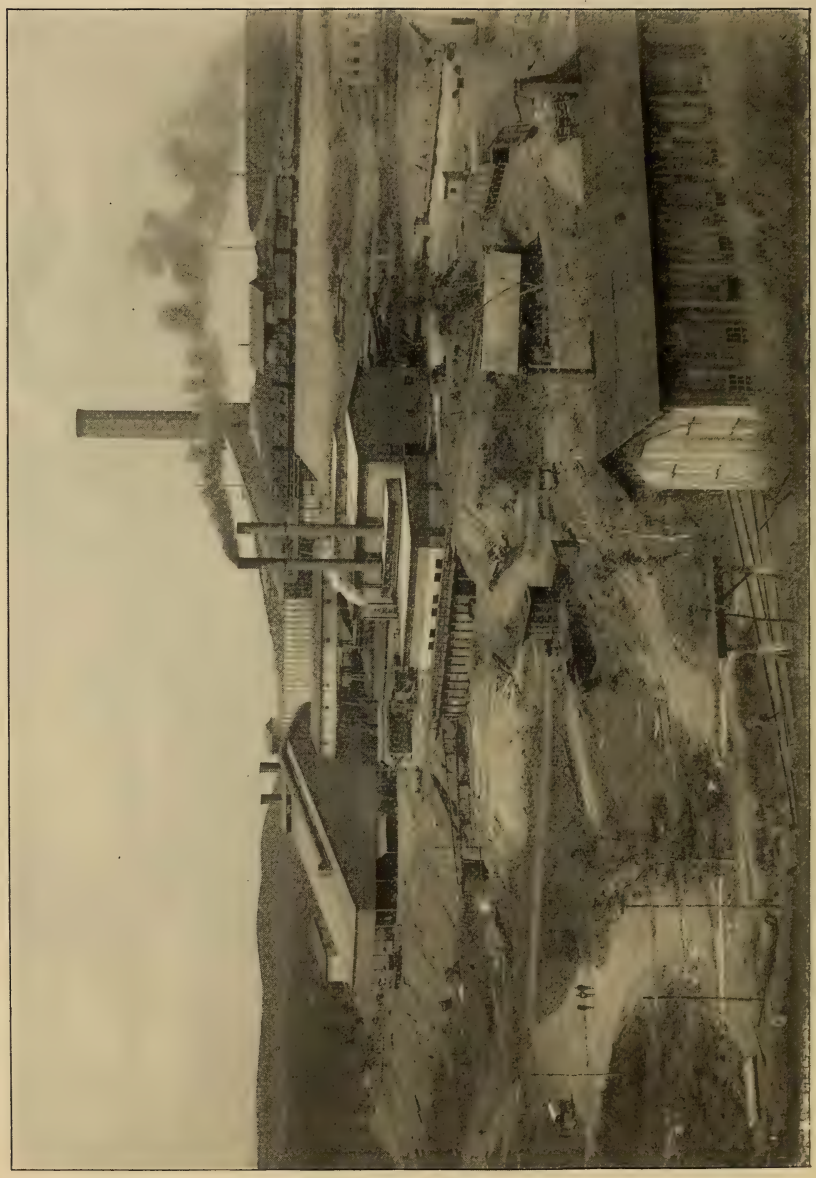
The resultant mineral from the stamp mills is sent to the smelting works and in one operation is converted into merchantable copper of a high grade.

At these smelting works the mineral is charged into reverberatory furnaces and melted down, and the slag is skimmed off. It is rabbled and poled,

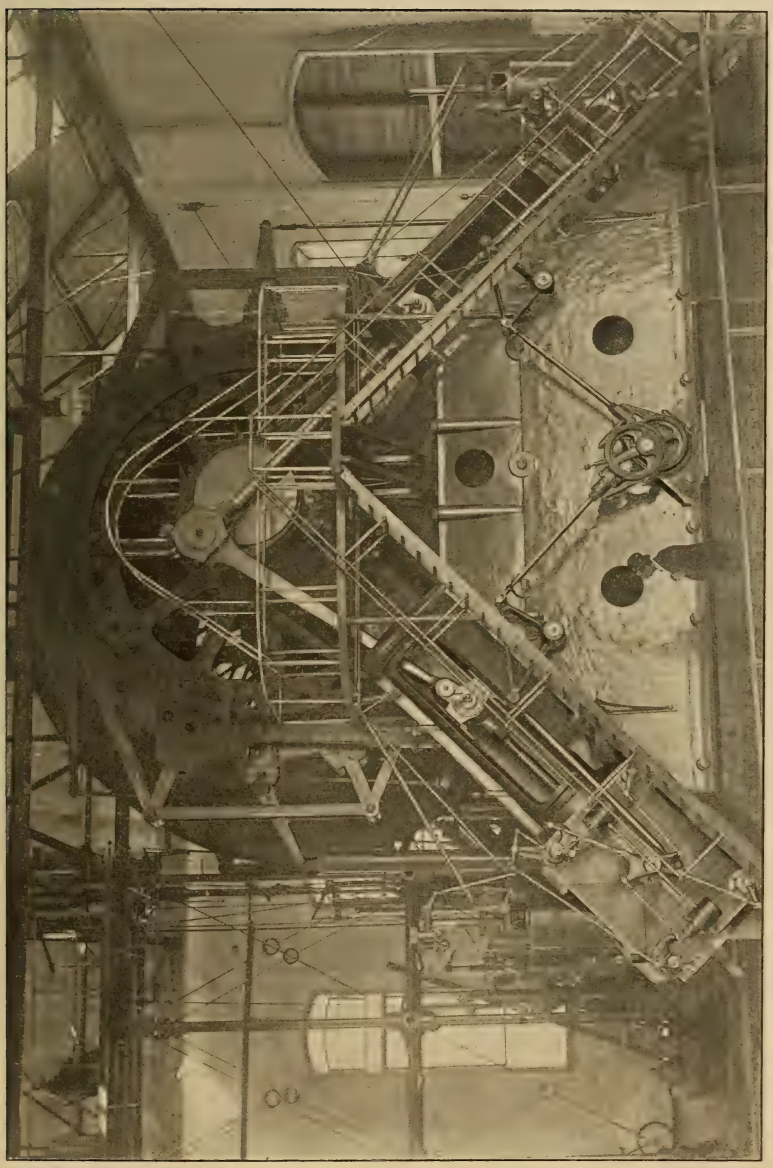
A MAN ENGINE IN THE QUINCY MINE AT HOUGHTON, MICHIGAN

which is locally known as "mineral," containing anywhere from 40 per cent. to 85 per cent. metallic copper, the balance being gangue rock. The tailings from the mill are swept out into the lake either directly from the lower end of the mill, or, if the level is too low, they are elevated by sand-wheels to get the proper height of discharge. The grade of the rock worked on Lake Superior is the lowest in the world, the Atlantic Mine yielding about fourteen pounds, 0.7 per cent., of copper per ton of rock, being then in a fit shape to be cast into ingots, cakes, or wire bars. The grade of "Lake" copper, as it is called, has always been high, though as the mines increase in depth arsenic is appearing in somewhat larger quantities, and now, in order to compete with the higher grades of "electrolytic" copper, the Calumet & Hecla treats part of its product by electrolytic refining at its works at Buffalo.

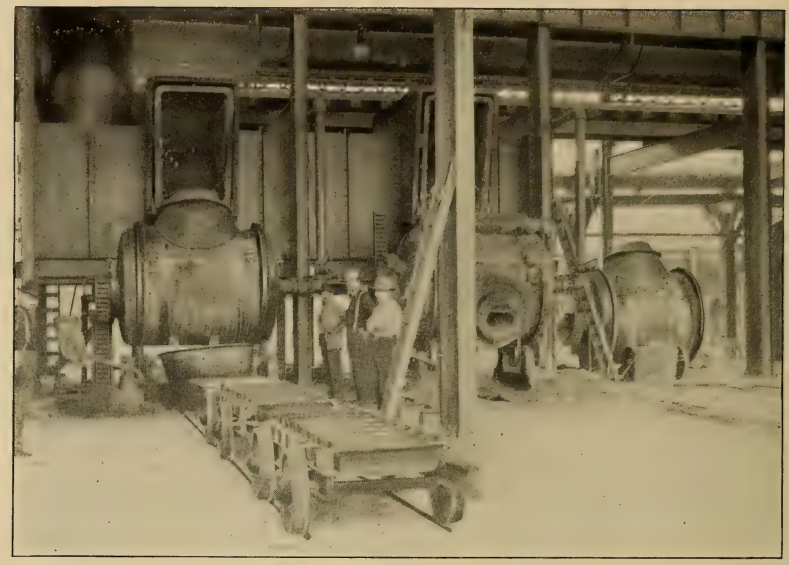
It is on Lake Superior, perhaps, that the best mining practice of the United



THE PLANT OF THE TENNESSEE COPPER COMPANY, AT COPPER HILL, TENNESSEE



FOUR-CYLINDER HOISTING ENGINE AT NO. 5 SHAFT OF THE TAMARACK MINE. VERTICAL DEPTH OF SHAFT, 4938 FEET



COPPER CONVERTERS AND LADLE CARS AT THE WORKS OF THE HIGHLAND BOY GOLD MINING CO., UTAH

States may be found, nothing approaching it, except the anthracite collieries of Pennsylvania. The district produces about 150,000,000 pounds of copper per annum. Of greater importance, because of the magnitude of its production, is Montana. This State now produces copper at the rate of about 250,000,000 pounds per annum. The whole of this production is from a little patch at Butte, covering not more than about two square miles of territory. There the Anaconda Mine, developed by the energy of the late Marcus Daly, holds rank as the foremost producer.

The veins in the Butte district are fissures and replacements in a much shattered granite area. The ore is, broadly speaking, a sulphide, being a mixture of the various sulphide copper minerals, along with iron pyrites, and having as a gangue a material high in silica. The ore bodies, as a rule, are very nearly vertical, and vary in width from seams too narrow to mine up to those measuring a hundred feet. The bodies are opened up by vertical shafts, the method of mining being by square sets and subsequent filling with waste rock. The ore is hoisted in some of the shafts in skips containing ten tons, and in others by two and three-decked cages.

The nature of the ore is such that it must undergo a preliminary dressing by water so as to eliminate part of the excess silica before it can be smelted. To this end, it is transported from the mines in railway cars to some convenient point, the new reduction plant of the Anaconda Company, situated at Anaconda, being a typical one, and containing a concentrator and smelting plant combined. Some idea of the magnitude of the operations may be gained from the statement that this new plant, which cost something over $2,000,000, has a capacity of 5000 tons of ore a day and is spread over sixty acres of ground.

The first building is the concentrator, which consists of eight sections, each one of which is capable of treating from 500 to 600 tons of ore a day. The soft and friable nature of the Butte ore does not permit its being profitably crushed by steam stamps, as on Lake Superior, and, therefore, crushers and rolls are employed. The crude ore of the Butte district carries from 3 per cent. to 10 per cent. of copper; after concentrating it runs from 10 per cent. to 20 per cent.

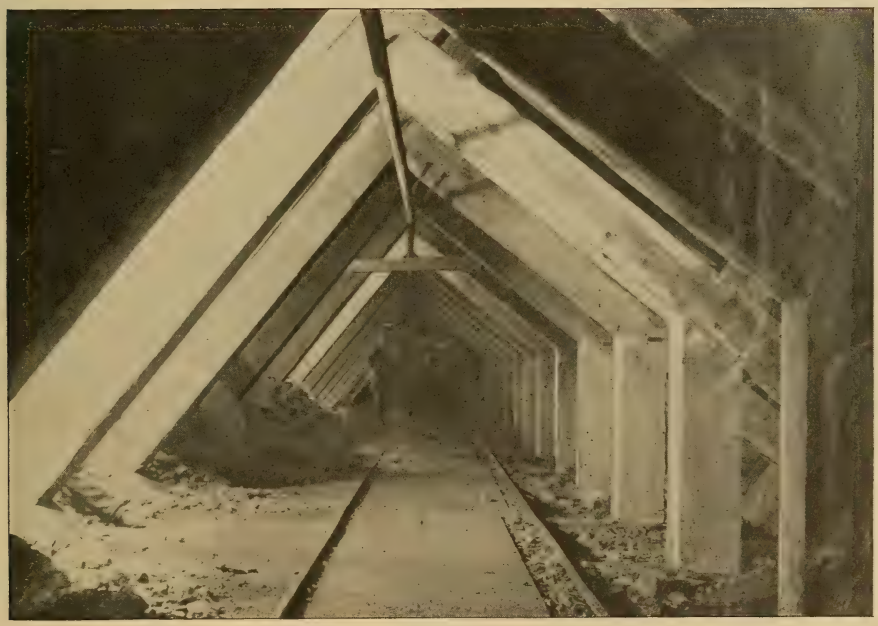
The concentrating machinery is similar to that used on Lake Superior, except that more regrinding of the middle products is done and the type of jigs used is somewhat different.

From the concentrator the fine concentrates are carried by railway cars to the roasting building. This contains forty-eight mechanical roasters, each with a capacity of forty tons per day. Here the fine material is roasted to drive away the excess of sulphur. Next the roasted ore is taken in standard-gauge cars to the reverberatory building, which contains fourteen reverberatory furnaces, each 50 by 24 feet.

The coarse concentrates and the high-grade, first-class ore from the mines, together with certain by-products and flux, are smelted in the blast furnace building. This contains five furnaces, each with 56 × 180 inches hearth area and 18 feet high, and each capable of smelting 400 tons in every twenty-four hours.

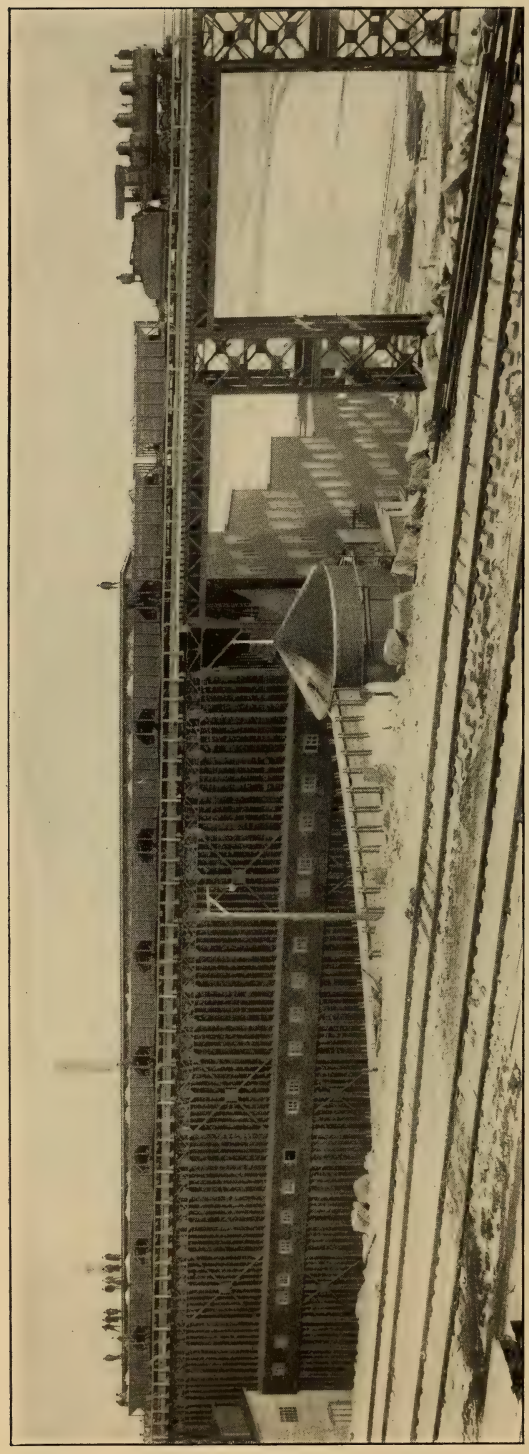
At the blast furnaces and the reverberatory furnaces, the copper is turned out in the form of a matte, carrying about 50 per cent. of copper. This molten matte is transferred in ladle cars, running on standard-gauge tracks, to the converter building, which contains eight converter stands, with shells 8 feet in diameter by 12 feet 6 inches long. Here, by a modification of the Bessemer process,* the iron and the sulphur are eliminated and a blister copper is made, which, after a crude refining, is cast into anode plates. These go to the electrolytic refinery, whence the pure copper, in the form of cathode sheets, is taken out, and the gold and silver and impurities sink to the bottom of the tanks in the form of a mud which is afterwards refined and the gold and silver are extracted.

While but little silver is found in the Lake Superior copper, that from Butte will usually carry from 30 to 100 ounces per ton, and frequently from a trace to 0.5 ounce of gold. Most of the Butte copper is so impure that the electrolytic method of refining is necessary, not



TIMBERING IN THE CALUMET & HECLA MINE

*The Bessemerising of copper mattes will be found treated of more at length in another article in this issue by Dr. James Douglas.



THE FIRST TRAIN LOAD OF ORE AT THE NEW ANACONDA REDUCTION WORKS, AT BUTTE, MONTANA, JANUARY 23, 1902

only to save the gold and silver, but also to eliminate the arsenic and antimony. The resulting refined copper made by melting down the cathode sheets in a reverberatory furnace is usually purer than "Lake" copper. Arizona has long been known as a district where much copper was to be found, but its arid climate, its distance from railways, the presence of hostile Indians, and the high expense of fuel have retarded its development.

In the earlier days of the country deposits of enormous richness were found, the ore occurring in bodies in limestone caves, and frequently running as high as 25 per cent. metallic copper. This ore was in the form of oxides and carbonates, and masses of the most beautiful green and blue crystals of malachite and azurite are everywhere to be found in the cabinets of collectors.

In those days, too, the metallurgy of this ore was extremely simple, and it may be said that it was the necessities of this district that developed the water-jacket furnace for copper smelting. Into these little water-cooled furnaces it was only necessary to shovel the rich ore along with coke which probably had been hauled a hundred miles across the desert and which cost $60 a ton at the furnace, when from the tap hole came a pot of copper to four pots of slag. It mattered not that this slag carried from 2 per cent. to 3 per cent. copper, and so thousands of tons of rich slag were thrown over the dump and bars of black copper were hauled back to the railway by the same freighters who had brought in the coke.

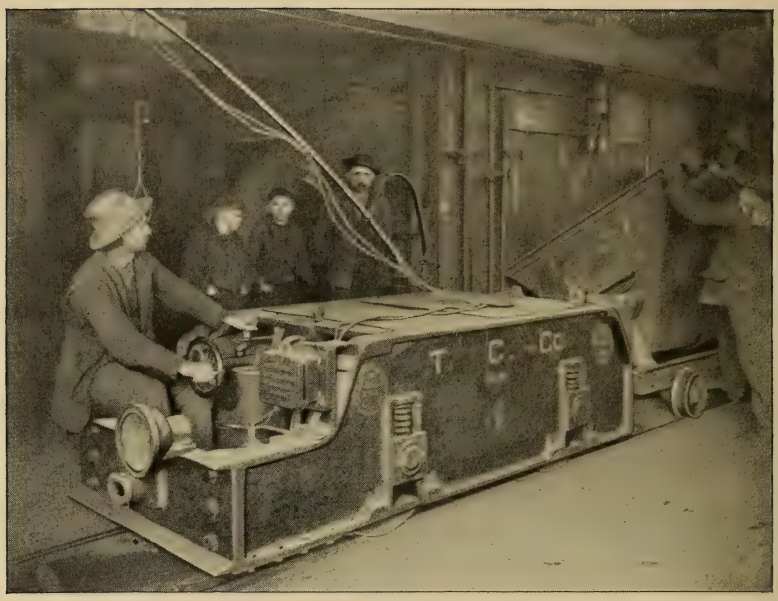
Conditions have improved since then, and, at the same time, the fabulously rich bodies of ore of that early period have been mined out. In their places have been found mountains, one with propriety may say, of extremely low-grade material, which is concentrated and smelted in much the same way as the ores of Butte. In the Clifton district, in Arizona, where the old Longfellow Mine in the early days produced rich carbonate ores, most of the product now comes from a porphyry mass containing from 2½ per cent. to 3 per cent. of copper in the form of chalcocite.

HEAP ROASTING OF COPPER ORE

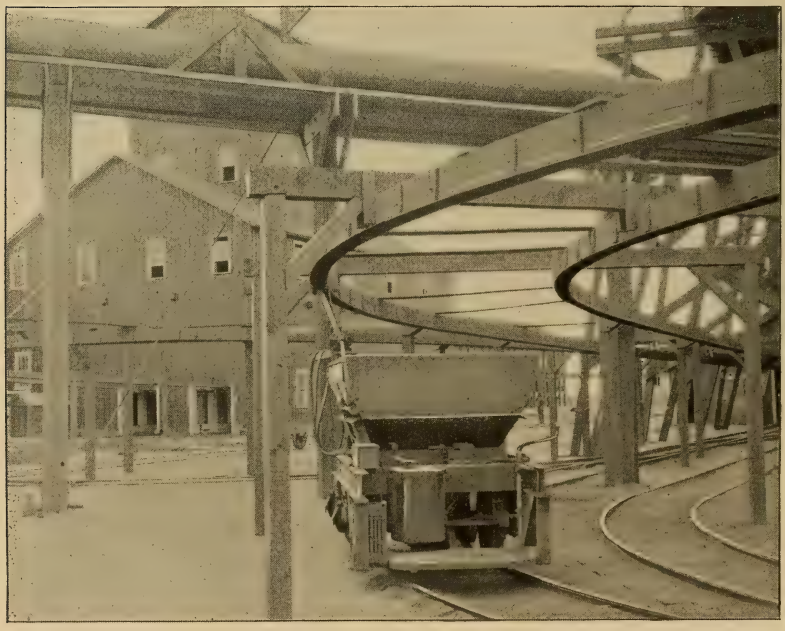
This is concentrated by water, smelted in blast furnaces, and the resulting matte is turned into blister copper by Bessemer converters.

In the Bisbee district, in Arizona, the ore bodies are oxidised, occurring in limestone, and appear to the eye very similar to the soft hematite deposits of Lake Superior. Fortunately, however, there are enough deposits containing sulphur, so that in the blast furnaces a matte can be produced with resultant slags holding not more than 0.5 per cent. of copper, as against an average of 2.5 per cent. if the material were smelted to black copper. Here the matte is treated in trough converters, introduced in the United States and perfected by Dr James Douglas, the Nestor of American copper metallurgists.

It is at Jerome, Arizona, that the largest copper mine owned by an individual exists. The United Verde Mine, the property of Senator W. A Clark, of Montana, consists of a large pyritic deposit situated in Archaean schists underlying the later limestones of the country. The ore is mined and run out of various tunnels from different levels in the hillside, where it is piled in heaps and roasted so as to drive off the excess of sulphur. After roasting, it is loaded into cars, and, curiously enough, is run back into the mine again. There, through a centrally located shaft, the roasted ore is hoisted to the surface, and, with a certain amount of unroasted and more silicious ore, is smelted in blast furnaces, converted in Bessemer converters, and turned into pig-copper high in gold and silver and shipped East for refining. The United Verde Mine produces, on an average, 40,000,000 pounds of copper per annum, con-



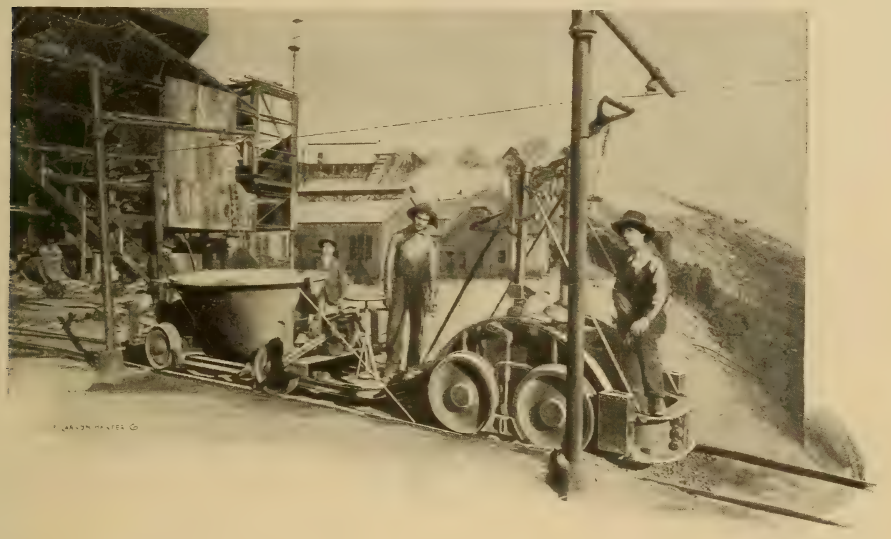
A BALDWIN-WESTINGHOUSE ELECTRIC LOCOMOTIVE DUMPING A CHARGING CAR INTO A BLAST FURNACE AT THE TENNESSEE COPPER COMPANY'S SMELTER



A MOTOR CHARGING CAR AT THE WORKS OF THE HIGHLAND BOY GOLD MINING COMPANY, UTAH

taining enough gold and silver to probably pay all the costs of extraction. The other principal district of Arizona is that around Globe, where the Old Dominion Mine has been operated for many years. It originally contained carbonate ores, but these have now given way to the usual sulphides.

California has but one copper mine of importance, and that is in Shasta County, owned and operated by the Mountain Copper Company, Ltd. There, thrusting itself above the surrounding hills, lay for years an immense mass of gossan, or iron ore, of apparently little or no value. Down near the base attempts had been made, with more or less success, to mine the lower portion of the mass and treat it in a stamp mill for silver. At last, someone realising that this "Iron Hat" must cap a sulphide deposit, drove in a tunnel, and the unaltered ore was exposed.



A SLAG LADLE TRUCK SUPPLIED TO THE UNITED VERDE COPPER CO., AT JEROME, ARIZONA, BY THE COLORADO IRON WORKS CO., DENVER, COL.

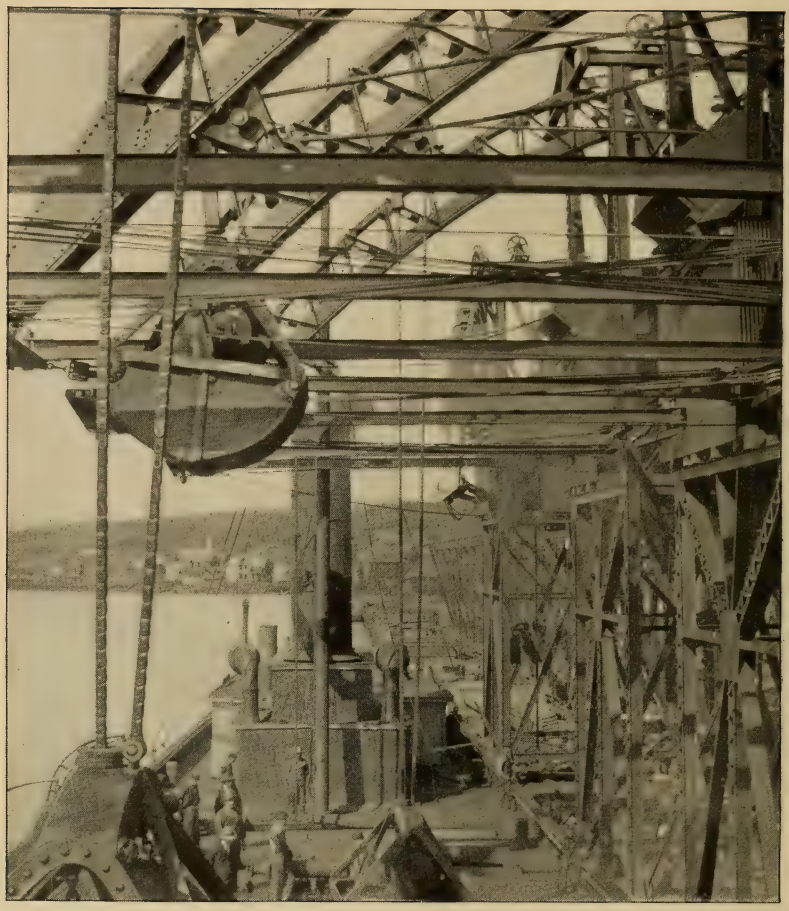
however, called "base," and considered of no value, until examined by Mr. Alexander Hill, of London, who recognised its great value.

erty was immediately developed, and to-day is a large and regular producer.

The ore is, in its character, similar to that of the great Rio Tinto Mines, in Spain, being a pyrite containing copper, but also, fortunately for the owners, gold and silver. It is mined in large underground chambers on square sets with filling, and is then brought down to Keswick, on the Sacramento River, by a narrow-gauge railway winding among the foothills, where it is roasted in heaps and smelted into matte, which at present is shipped to the Atlantic coast for refining. A converter plant has just been erected, and will, no doubt, soon be in operation.

The southern part of California carries a series of copper-bearing pyrite deposits in the schists, running parallel to the great gold-bearing mother lode. None of these are of great importance, but in the days of the Comstock activity they were relied upon to furnish the blue vitriol used in the silver mines of Virginia City, Nevada. Some of these mines are located most attractively among the foothills, often in close proximity to wheat fields and fruit ranches. The copper production of California is about 30,000,000 pounds per annum.

For a great many years no one for a moment would have imagined that Utah



ORE HANDLING PLANT OF THE CALUMET & HECLA MINING CO., AT LAKE LINDEN, MICH., INSTALLED BY THE C. W. HUNT CO., OF NEW YORK

would ever become a producer of copper, and yet about four years ago, in Bingham Cañon, one of the oldest camps in the State, a deposit of copper was uncovered from which 500 tons of ore a day are now being extracted. Somewhat like the Mountain Copper Mine of California, the oxidised ore of the Bingham district had been wrought in the early seventies for gold. The ore, however, was refractory, and the extraction seldom amounted to 50 per cent. of the gold contained. In 1897 Mr. Samuel Newhouse purchased the Highland Boy Mine, and proceeded to erect upon it a cyanide mill for the purpose of treating its oxidised gold ores by that process. The stock of the company was very modestly floated on the London market at about seven shillings a share.

By the time the cyanide mill was completed and had started to run, the lower tunnels of the mine had penetrated into a body of sulphide ore, carrying, in places, as high as 17 per cent. copper, from 6 to 7 ounces of silver, and up to 0.5 ounce of gold. The cyanide mill was hastily abandoned, the development of the mine rushed, and a smelter built in the Salt Lake valley, the stock going up from seven shillings in progressive steps, reaching at one time on the London market £10 per share.

The ore in the Highland Boy Mine

occurs as a pyrite, replacing a limestone which lies between quartzite walls. The deposits vary from 20 to 200 feet in width, and at present are being operated on the top slice caving system, a modification of the North of England caving system, as developed on the Mesabi iron range of Minnesota. From the mine the ore is transported on an aerial ropeway to Bingham Junction, and thence in railway cars to the smelter.

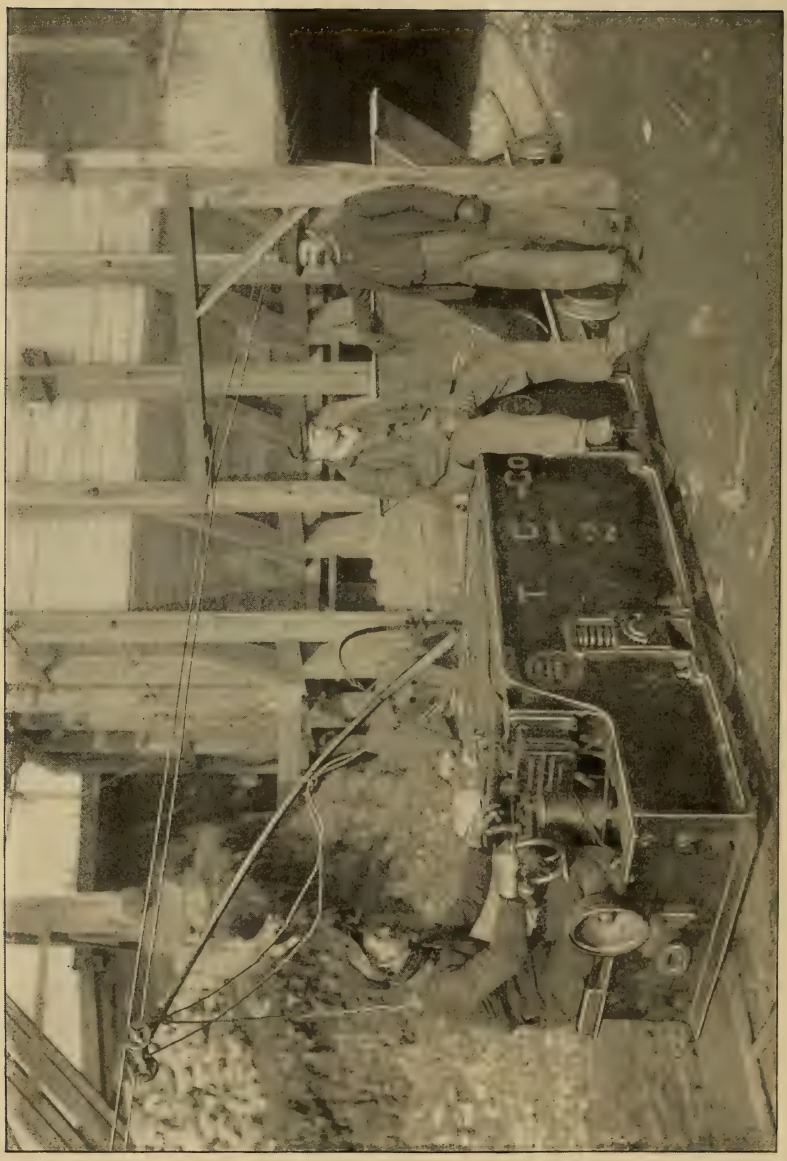
This smelter was designed by Mr. Frank Klepetko, who is also the designer and manager of the already mentioned new plant at Anaconda. A most complete system of mechanical handling is installed, comprising electric charging cars and slag cars, electric elevators, and an electric crane. Roasters, reverberatory furnaces and Bessemer converters comprise the smelting appliances. From the time the ore is shoveled into the tramcars at the mines it is never touched again by a shovel, and finally emerges from the works as pig-copper at one end, the waste slag going out at the other.

The opening up of the Highland Boy Mine stimulated exploration in the district, and now three other copper mines are in operation; one, the Bingham, with a completed smelter; the second, the United States, with smelter under construction; while the third is still in the development stage.

From California it is a long cry to the Apalachian range, and yet, curiously enough, to a certain extent the conditions at the two extremities of the country are somewhat similar. Following along the east flank of the Apalachian range, similar to the ore deposits along the western foothills of the Sierras, there lies a chain of sulphide deposits extending from Nova Scotia to Alabama. These, in places, carry copper, and, in the early days of the United States, were extensively wrought. Then came a period of decadence, and it was only within the last ten years, and particularly within the last three years, that attention has again been directed to them.

The principal deposits are in the Ducktown basin, which is situated in the extreme southeast corner of Tennessee, at an altitude of 1600 feet, and in the heart of the Great Smoky range. The dis-

THE COPPER QUEEN MINE AT BISBEE, ARIZONA



A BALDWIN-WESTINGHOUSE DOUBLE-TROLLEY LOCOMOTIVE AT THE SMELTER OF THE TENNESSEE COPPER COMPANY, COPPERHILL, TENNESSEE

CARRYING COPPER ORE ON A BELT CONVEYOR MADE BY THE ROBINS CONVEYING BELT COMPANY, NEW YORK

trict was opened up in the early fifties, and the rich black ore, or oxy-sulphurets, found between the gossan and the unaltered sulphides, was mined. These ores ran as high as 50 per cent. copper, and were at first boxed, hauled across the mountains to Cleveland, Tennessee, and shipped to Swansea, Wales, where they were treated. Later on, smelting plants were built at Ducktown, and refined copper was produced. Finally, in the late seventies, the black ore was exhausted, and the unaltered sulphides were not at that time thought sufficiently rich to work.

At present two companies are working in the Ducktown district, which, between them, control all of the mineral deposits. The Ducktown Sulphur, Copper & Iron Company, Ltd., has been in operation for about ten years, but produces only copper matte. The Tennessee Copper Company has just completed a very extensive plant, and is now mining ore at the rate of about 250,000 tons a year. Three mines have been opened up, and one of them, the Burra Burra, shows probably one of the largest and most massive sulphide deposits in the eastern part of the United States. The ore is a pyrrhotite, carrying from 2 per cent. to 3½ per cent. copper. The deposit varies in width from 75 to 90 feet, and has been opened up 600 feet long and to a depth of 400 feet. The gossan outcrop would seem to indicate this ore body to be from 1500 to 2000 feet in length. It is almost entirely free from rock of any kind.

The Burra Burra Mine has been equipped with a modern power plant containing water-tube boilers, a first-motion hoisting engine, and a large two-stage, cross compound air compressor. The ore is hoisted and dumped into a shaft crusher house, 127 feet in height, where the ore is crushed to pieces about 4 inches in diameter.

The product from the three mines is brought in standard-gauge railway cars to the roast yard, where heaps are built and the ore is roasted. At the end of about seventy-five days the roasted ore is brought to the smelter and there converted into pig-copper, being treated in large blast furnaces, the resulting matte being blown into copper in trough converters.

The furnaces are charged by two-ton cars drawn by electric locomotives, and a similar locomotive is used for the handling of the slag pots. One furnace

for the last six months has averaged 465 tons of charge per twenty-four hours. During the month of January, 1902, the average was 548 tons of charge per day. The power plant at the smelter is somewhat unique in the use of horizontal blowing engines instead of the usual rotary blowers for furnishing blast for the furnaces.

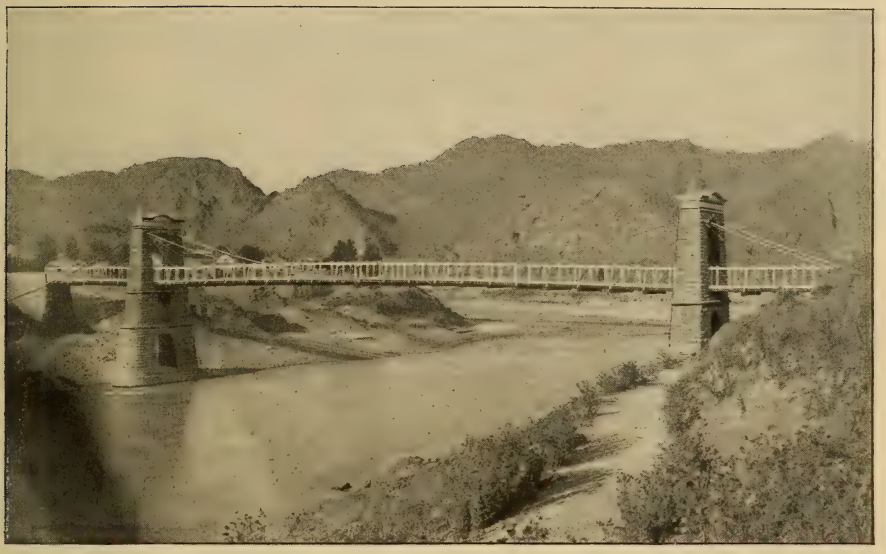
The Tennessee ore is low-grade, but the cheap labour and fuel of the country, in connection with modern methods of handling, have made available material which, ten years ago, it was confidently predicted would never be mined. The probable production of the two companies in Tennessee will be from 15,000,000 to 25,000,000 pounds per annum.

Copper is also found in Wyoming, Washington, Oregon, Colorado, and New Mexico, but no large deposits have yet been developed. The total product of the United States is about 600,000,000 pounds per annum.

The supply of copper in the United States, unlike that of iron, cannot be called unlimited. As will be seen, it is found but in few districts, and the expense of extracting it is high, and requires the expenditure of large amounts of money for plant and development. Even when discovered, a new mine cannot be put into profitable operation in much less than from two to three years, and its plant, as a rule, must include either an expensive concentrating mill or a smelter.

GOLD DREDGING IN NEW ZEALAND

By H. E. Duncan



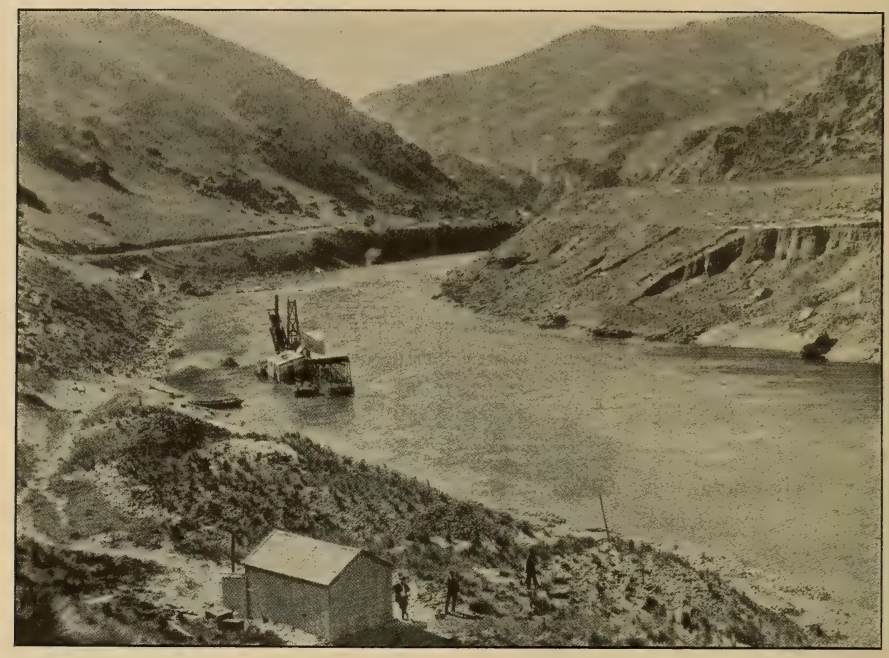
ALEXANDRA BRIDGE OVER THE CLUTHA. THE PRINCIPAL CENTER OF THE DREDGING INDUSTRY

DREDGING for gold is a departure from ordinary gold mining that has completely revolutionised that industry, so far as Central Otago, in New Zealand, is concerned. It has long been known that the rivers of Otago contained gold in considerable quantities, and various attempts have been made to get at it, but it is only within the last ten years that miners have been successful in getting it in paying quantities.

The miners in New Zealand may lay claim to the honour of having invented the dredging industry and brought it to its present perfection. Truly, necessity has never before been more instrumental in bringing out the recourse of man than in this case. For years the miner has been in the tantalising position of knowing that a fortune was lying at the bottom of the rivers, and it is only after many failures that he has at last evolved a machine that will bring up the gold that has lain hidden there for thousands of years.

The River Clutha, or Molyneaux, is the largest in New Zealand and heads from Lake Wanaka, and its chief tributary, the Kauarau, comes from Lake Wakatipu. The two lakes have an area of over 200 square miles, and, by acting as reservoirs, regulate the flow and prevent floods. The fall of the Clutha from its source to the sea averages about 10 feet per mile, and the current is, for the most part, very rapid,—about eight or ten miles per hour.

In 1864 the government had the volume of the river carefully measured at a time when the water was low. The flow was then 1,690,400 cubic feet per minute. The following affords an interesting comparison with some of the well-known rivers in the Northern Hemisphere:—



DREDGING IN CLUTHA RIVER

	Cubic Ft. Per Minute
Thames	102,000
Tiber	618,000
Nile	1,386,000
Clutha	1,690,000

Thus the Clutha is larger than the Nile and sixteen times the size of the Thames.

The country through which the Clutha passes is varied in character. At one place mountains tower abruptly on either side, and at another the river flows through extensive low-lying flats. The country is absolutely devoid of timber, and vegetation of any kind is very scarce. The bed rock is chiefly sandstone and interstratified with this are beds of lignite which provide cheap fuel for steaming purposes.

The old Alexandra Suspension Bridge, shown on the preceding page, which is now being replaced by a steel one, crosses the Clutha just above its junction with the Manuherikia, and immediately beyond the bridge lies the mining township of Alexandra, which is the chief center of the dredging industry.

The flats extend along the river banks from Alexandra to Clyde, about six miles. These flats, which stand about 40 feet above the level of the river, contain a small percentage of gold, and the time will come when the whole of this area will be dredged.

Dredging was started in 1863. The first primitive dredge consisted of a raft, made by securing a few planks to a couple of barrels, on to which the material was shovelled by a man standing in the water. The raft was then hauled to the shore and the material cradled in the usual manner. The next step was the spoon, which was first employed on the Clutha in 1864. The spoon consisted of a steel hoop to which was attached a bucket of cowhide, capable of holding about 6 cubic feet of material. This was fixed to one end of a long spar, the other end being attached to the stern of the pontoon by a pivot; a windlass at the bow was used to lower and raise the spoon. The material, when brought on deck, was treated in an ordinary miner's cradle, but even under very favourable conditions not more than two and one-half tons per hour could be handled in this way.

Some of these dredges were very successful, and a boom in spoon dredges set in. The cost in labour, six men being required, soon prompted further improvements, and the next development took the form of current-wheel dredges, which were provided with undershot wheels driven by the flow of the river. These were the first dredges built with a chain of buckets. The latter discharged into sluice boxes which were supplied with water from a centrifugal pump or small buckets attached to the wheel. Some of these dredges are still working quite successfully.

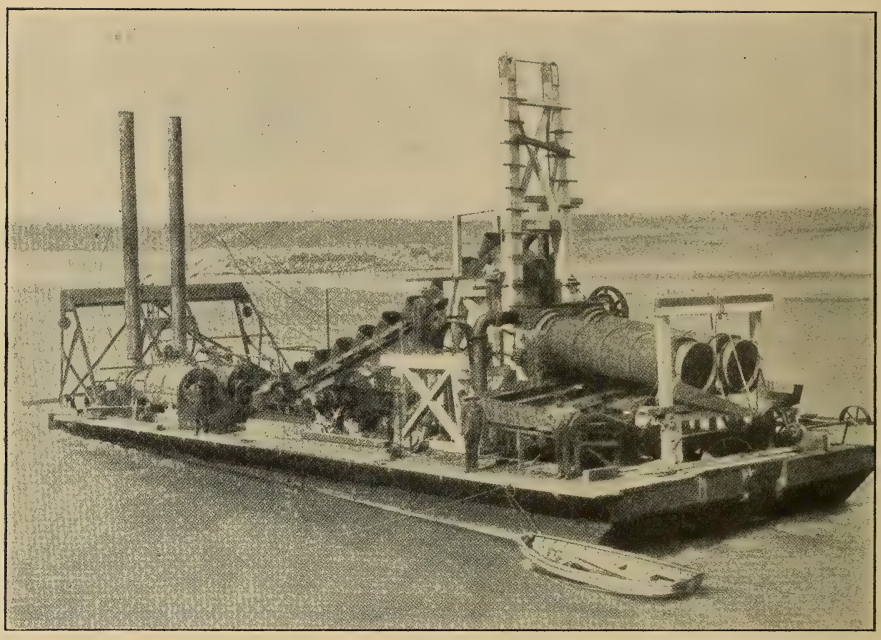
Their disadvantages were that they were obliged to keep in the middle of the stream, and could, therefore, not work the sides. They were also not sufficiently powerful to work the deep ground, and then, too, a number of stoppages became necessary through the river rising.

The introduction of steam in 1881 may be taken as the time from which the dredging industry was an assured success. Steam enabled the dredge master to be independent of the current and to work along the bank as easily as in the centre of the stream, and when the river was high to run into the eddies and backwaters where the dredge would not float when the river was at its normal height.

The form of table in use was the ordinary sluice box, consisting of a box about 3 feet wide with perforated plates about an inch from the bottom. On top of these was laid cocoa matting, the buckets delivering directly on this. The consequence was that a great percentage of gold was lost, as owing to the jolting of the table, caused by the work of the buckets, the gold was nearly all washed down the tables along with larger material.

Screens were next introduced. A typical dredge has the following leading dimensions:—Length, 109 feet; width of beam, 25 feet 6 inches; depth, 7 feet. The ladder is 75 feet long, designed to dredge to a depth of 50 feet from the surface of the water. The buckets are of 5½ cubic feet capacity. The engine

THE BEGINNINGS OF A NEW ZEALAND DREDGE



ANOTHER CONSTRUCTION VIEW. THE DIRT RAISED BY THE BUCKETS IS DISCHARGED INTO THE TWO REVOLVING PERFORATED CYLINDERS SHOWN AND IS THERE WASHED BY SHOWERS OF WATER

is a 16-horse-power compound. Surface condensation is effected by the water raised for gold-saving purposes.

The winch is driven by a pair of horizontal engines, fitted with reversing motion. The boiler is of the Cornish multitubular type, the working pressure being 150 pounds per square inch. The ladder is raised and lowered in the usual manner from a winch. The buckets are put in motion by a tumbler driven by gears and rope drive from the engine.

The material is delivered on to a drop plate, and thence into a perforated screen, the fine stuff falling through the screen on to gold-saving tables. The material in the screen is washed by water from perforated pipe running all through the screen, and the tables are supplied with an additional supply by branch pipes at the back of the screen. The water is supplied by a centrifugal pump, driven from the engine by a belt. The coarse material that will not pass through the holes in the screen is delivered into a stone shoot and passed directly overboard into the current, or elevated by means of an elevator.

The pontoons are usually built of wood, though in some cases steel has been used.

The illustration on page 273 shows a dredge pontoon in course of construction. It is usually built on the bank of the river close to where the dredge is intended to work. The pontoons are narrower at the bow than the stern. This construction permits the working out of corners and using a narrower paddock. The pontoons are divided by a well at the fore end and are tied together by means of a gantry.

The length of a pontoon varies according to the nature of the ground to be worked, and depends also upon whether an elevator is to be used, so that no direct rule can be laid down as to the size of pontoon until the ground has been tested.

The engines are all built in England. The boilers used are usually of the multitubular pattern, and are mostly built either at Dunedin or Melbourne. The

winch consists of six barrels, each working independently, usually with friction gear, five of the lines leading from the barrels being required to keep the dredge in its position and one to raise and lower the bucket ladder. The length of this bucket ladder depends on the depth of ground to be dredged. It is sometimes made telescopic.

The tumblers are usually constructed of wrought iron with movable pieces so that they can be replaced when worn. They were formerly made of cast iron, but their life was so short that wrought iron has now been almost entirely adopted. The plummer blocks carrying the tumbler shaft are set on a gutta percha block to lessen the effect of a sudden stoppage. The buckets are made with strengthening pieces at the sides and around the lips. The lip piece can be easily removed, its life being only about two years on hard ground. The buckets ride on movable blocks keyed to a strong shaft.

Grip hooks with replaceable points are fixed on the bucket chain to dig up the ground and lift large boulders. A three-pronged corner piece is also keyed on to the shaft at the side of the bottom tumbler to loosen the ground. A grating is fixed at a slope over the well to throw off stones that drop from the buckets.

The drop shoot is made movable, and is attached by means of two arms at an angle, one being fixed to the top of the ladder, and the other to the top of the shoot. The fulcrum is about the middle of the ladder. Thus, when the ladder is shifted, the drop shoot is moved in a corresponding degree. The screen is set at a pitch of 1 in 11. On the inside a spiral flange of angle iron runs from top to bottom to hold back the material and ensure it being efficiently washed. The diameter of the screen should be such that when it revolves the material will mount up on the sides and tip over and not merely slide after rising a certain height, a good diameter being 3 feet 6 inches. If this is not enough to allow all the material to be thoroughly washed, a second screen should be added.

The screen should not be geared on to the same shaft as the tumbler, because if the bucket strike hard wash the teeth on the screen would be stripped. At the end of the screen is a small drop shoot to guide the material on to the elevator.

The holes in the screen are generally graduated from ½-inch to ⅝-inch diameter and 1 to 1½-inch pitch, the larger holes being at the lower end. The holes are punched from the inside, the die being larger than the punch, to insure the outside being a little larger than the inside This prevents material lodging in the holes.

The water pipe inside the screen is perforated so as to wash the material through the holes in the screen. No water must flow down to the end of the screen, as it might carry gold with it. An outside pipe runs beneath the screen and over the tables to wash the material down the tables.

A distributing box is fixed below the screen and above the table to spread the wash evenly over the tables, the object being to keep the material finely and evenly spread on the table. The tables are set at a pitch of 1 in 10 to 1 in 12. They are usually adjustable, so as to vary the pitch as occasion may require.

The crew usually consists of six men and a dredge master, and in some cases of one or two cadets. The men work in eight-hour shifts.

The winch man is in charge of the shift. He is in such a position that he has the up-coming buckets fully in view and can regulate the amount of material lifted per bucket by raising or lowering the ladder according to the nature of the ground. Should a boulder be lifted, which would be likely to damage the screen, he either breaks it with a hammer, or, if too large, stops the buckets and levers it off. Boulders up to a ton in weight are sometimes raised in the grab hooks.

When it is found that a boulder is in the way and the buckets are fruitlessly hammering at it without raising it, the winch man pulls to one side and with the buckets excavates a hole along-

side until the boulder rolls over from its former position.

The dredge is kept in position by five steel wire mooring lines, two on either side and one head line. The shore ends are fixed to stout planks buried in the ground in some cases, the cables being 400 to 500 yards long. The laying out of the cables is heavy and laborious work, and, where possible, horses are used to drag them along the ground into position.

In opening out a paddock the buckets are gradually lowered until they begin to open out a cut in the ground. They are then lifted and the dredge is hauled to one side about the width of a bucket, by means of the side lines the bucket being again lowered. This lateral motion is continued until there is a cut the full width of the dredge. The dredge is then advanced two or three feet and worked laterally over the face of the cut. This operation is continued until the bed-rock is reached. The buckets can then be kept on the bottom and the paddock is said to be opened out.

The material passing from the buckets into the revolving screen is there broken up and washed by the jets of water, the small wash passing through the perforations on to the tables where it is again washed by water from the outer pipes. The gold, being heavier, is deposited on the matting, while the residue is washed over the table and down the chutes back into the river. The heavier material, or tailings, passes out of the end of the screen on to the tailings elevator by which it is stacked up behind.

As will be seen, the winch man is the most important, as on him depends the whole working of the machine. If he sees that the material contains much gold, he so regulates the buckets that they will bring up only half loads at a time so as to ensure the material being thoroughly washed. If, on the other hand, he be passing non-gold bearing gravel, he will crowd on full loads in order to get it out of the way as quickly as possible. He has also to see that the paddock is properly cleaned up and that the corners are thoroughly cleaned out. If this be not done the face will be gradually narrowed at each cut until it will be only as wide as the buckets, and he will then have to open out again.

Care has to to be taken to keep the dredge perpendicular to the face, as otherwise the tailings will be stacked on ground that has not been worked instead of in the paddock, with the result that in coming back to start the next cut the tailings will have to be removed again before getting down to the payable ground. He also looks after the tables. The engine man looks after the engine and boiler and running gear.

The top mats are washed up daily by the dredge master in the presence of one of the men, the bottom mats being washed only once a week, as a rule, unless there is an exceptionally good return on the top ones. The mats are first washed in a large wooden box kept for the purpose. They are then taken out and the water is run off. What remains is run over a small cradle with a table and matting to catch the gold. This mat is taken out and washed in another vessel, the water being run off. The gold is then put into a small pan and washed in the usual way, being finally dried over a stove and the dust blown off with bellows. It is again washed to take out any remaining impurities. It is then dried and weighed and taken to the bank, and the banker gives a receipt for the amount, the two men signing a book kept for the purpose at the bank, stating the weight of gold. The gold found in Otago is almost pure, and is worth, on an average, £3 17s. 6d. per ounce.

It is very difficult to obtain any reliable information as to the actual cost of working, owing to the lax manner in which accounts are kept and the unwillingness of dredge owners to impart information. Public companies are required to send in weekly returns of the number of men employed, with wages and the amount of gold obtained; but no official information is forthcoming of the amount of coal used, cost of repairs, and general upkeep.

Accordingly, the figures here given are far from satisfactory, and are mostly

compiled from personal observations. Taking a modern dredge, with a dredge master, six men, and two cadets or apprentices, the weekly cost is as follows:

	£		
Fuel. 16 tons of lignite at 12 shillings	9	12	0
Labour. Dredge master	5	0	0
6 men at £3	18	0	0
2 cadets at £1	2	0	0
Repairs £200	4	0	0
Depreciation (per annum) at 10 per cent per annum £6,500	12	10	0
Oil waste, &c.	1	0	0
Office expenses	3	0	0
	£55	2	0

The Golden Beach Hydraulic Dredging Company dredge has buckets of 6 cubic feet capacity. Taking this at twelve buckets per minute, we have 72 cubic feet per minute, 4320 cubic feet per hour, or 160 cubic yards per hour. Assume that the buckets, on an average, are half full, which, when losses are taken into account from stoppages and when working the bottom, is a fair average, and we have 80 cubic yards per hour. The total weekly cost being £55 2s., we find that the cost per cubic yard is 1.15d.

It is again difficult to estimate the percentage of gold saved in working. Captain Longridge gives it at 90 per cent. This the author considers too much. Ground has been known to have been worked over profitably a second time, so that the loss must have been greater. The author considers, and it is the opinion of a great many practical men, that 75 per cent. is much nearer the mark. Supposing the ground to contain 1 grain of the precious metal per cubic yard (roughly valued at 2d.), we have a return of 11,520 grains less 25 per cent., or a net return of 8640 grains, which, at 2d. a grain, is equivalent to £72 per week.

From this we see that it is possible to work a modern dredge at a profit if the gravel contains 1 grain of gold per cubic yard. The figures here reached, 1.15d. per yard, are certainly lower than the average on the dredges now at work, which is probably not less than 1.6d. per yard, but as dredges are now being built larger, there is no reason why the cost should not come down to 1d. per yard. Mr. Jackuet gives the profits of the Jutland Flat Company, working for two years, as follows:—

	1896	1897
Dredging wages	6,171	5,846 hrs.
Actual lifting during period	5,678	5,518 hrs.
Estimated quantity lifted	402,919	398,608 yds.
Gold obtained	1,159	1,177 oz.
Average yield	1.35	1.41 gr. per yd.
Paid in dividends	£1,125	£1,875

In 1896 a sum of £707 was expended in litigation. If this amount be added, the actual profits for that year, after deducting all expenses, will be £1832. Deducting profits from returns, leaves £5251 for working the two years. The total amount of material lifted was 801,627 cubic yards, making the cost per cubic yard 1.42d.

The government returns show that forty-two dredges which have started since the beginning of 1891 with a capital of £238,000, have won £436,975 worth of gold, and have paid upwards of £150,000 in dividends, equal to 64 per cent. The average time of running being three years for the whole of the dredges, gives a dividend of 21 per cent. per annum.

It seems to the author that the part most promising for further improvement and the one which is the most defective is the gold saving apparatus. Owing to the vibration set up by the machinery the material on the mats does not spread uniformly. The tables are not sufficiently large to ensure the material being properly treated. This may be overcome by placing the tables on a separate pontoon, which would also ensure the tailings being deposited further away from the spot worked by the buckets.

In the higher reaches where coal is dear, electricity might be used more extensively. This might be brought about by again using a separate pontoon, this time for an undershot wheel driving a dynamo, the power being conveyed to the dredge by means of cables. This would enable the dredge to work the banks of the current as is now done by the steam dredges.

CANADA AS A STEEL PRODUCER

THE OPERATIONS OF THE DOMINION IRON & STEEL COMPANY

By A. J. Moxham, Vice-President of the Company

THE seaport of Sydney, Cape Breton, the seat of Canada's new steel venture, has been noted for years as one of the safest and most convenient harbours on the American coast. It consists of two bays, with a protruding peninsula between, and is protected by a natural breakwater. One of these bays is four miles in length and the other four and one half miles, affording an available wharf line of sixteen miles of protected water. The depth is such that the largest vessels can utilise every portion, and the customary berths of the visiting men-of-war are practically in the "heart of the town." The harbour itself is rarely visited by fog. Indeed, although located not far from the "Banks," it has evidenced a good deal less fog during the two years of the writer's residence there than that which is accepted without comment in New York Harbour, for example. Even when the neighbouring ocean is fog-shrouded the entrance to the harbour is generally clear, and its safe approach has made it a favourite with navigators.

The climate is excellent. Sydney's latitude is about 150 miles south of Paris, and hence compares with what is considered a warm zone in Europe. While, however, its latitude would indicate a warm climate, the fact that the Arctic current bathes its shores gives a cool summer; strange to say, on the other hand, the winters are generally warm. Accurate records, lasting over the preceding two years, show that in

FIG. I.—THE LOW-LEVEL PIER FROM WHICH FINISHED MATERIAL IS SHIPPED

winter the temperature has not been lower than 2 degrees below zero (and for only three days of both winters did it get as low as this), and not above 80 degrees in the warmest days in summer. During the summer after sundown the temperature drops, with rare exceptions, to about 65 degrees. There are really but two seasons, winter and summer. Spring and autumn, as distinctively developed in the States, are lost in Sydney, in the fact that the late winter and late summer do not permit of more than two clearly distinguished seasons. For two years,—1899 and 1900,—the average winter temperature at Sydney has been as follows:—

November	30°	Fahrenheit
December	31°	"
January	25°	"
February	21°	"
March	27°	"
Average for winter	28 3-5°	"

While local ice exists in the harbour during the winter months, it amounts to but little, and the government records of the closing and opening of the harbour for the past ten years show that the harbour has been closed on an average of only twenty and one-half days per year. A very large tug would suffice to keep it an open port, so far as harbour ice is concerned. For a few weeks in the spring the drift ice is something that needs watching, but this is of short duration, and at such periods Sydney's shipping can be conducted

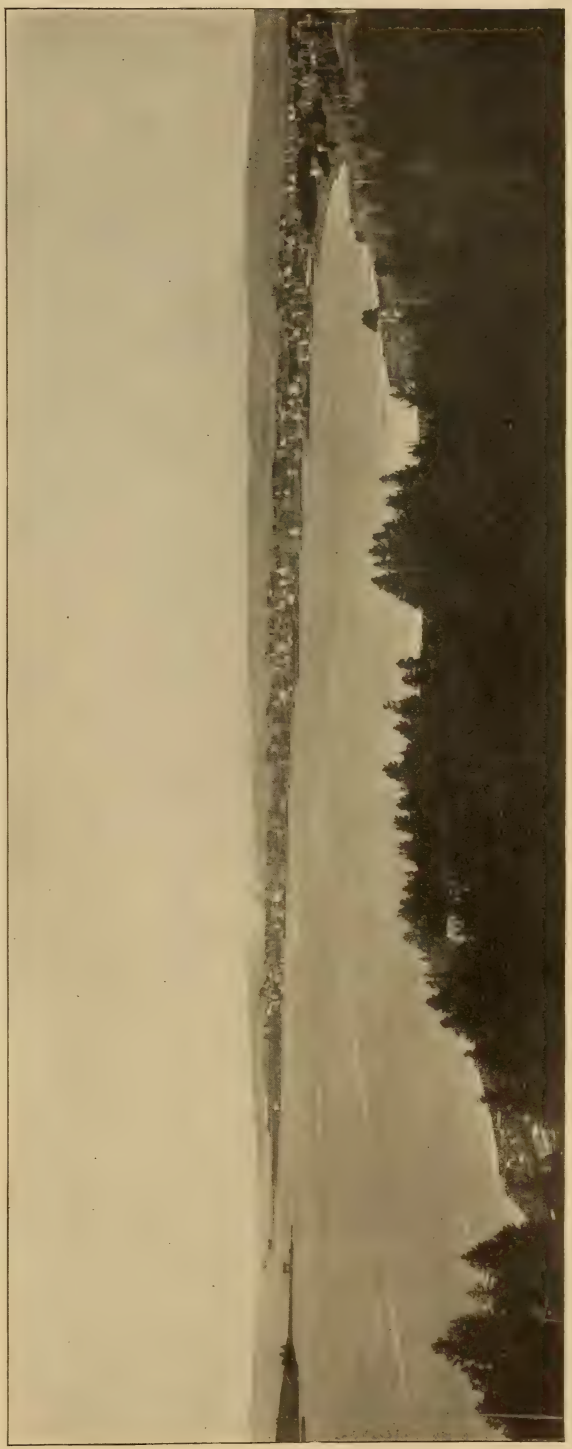


FIG 2.—THE TOWN OF SYDNEY

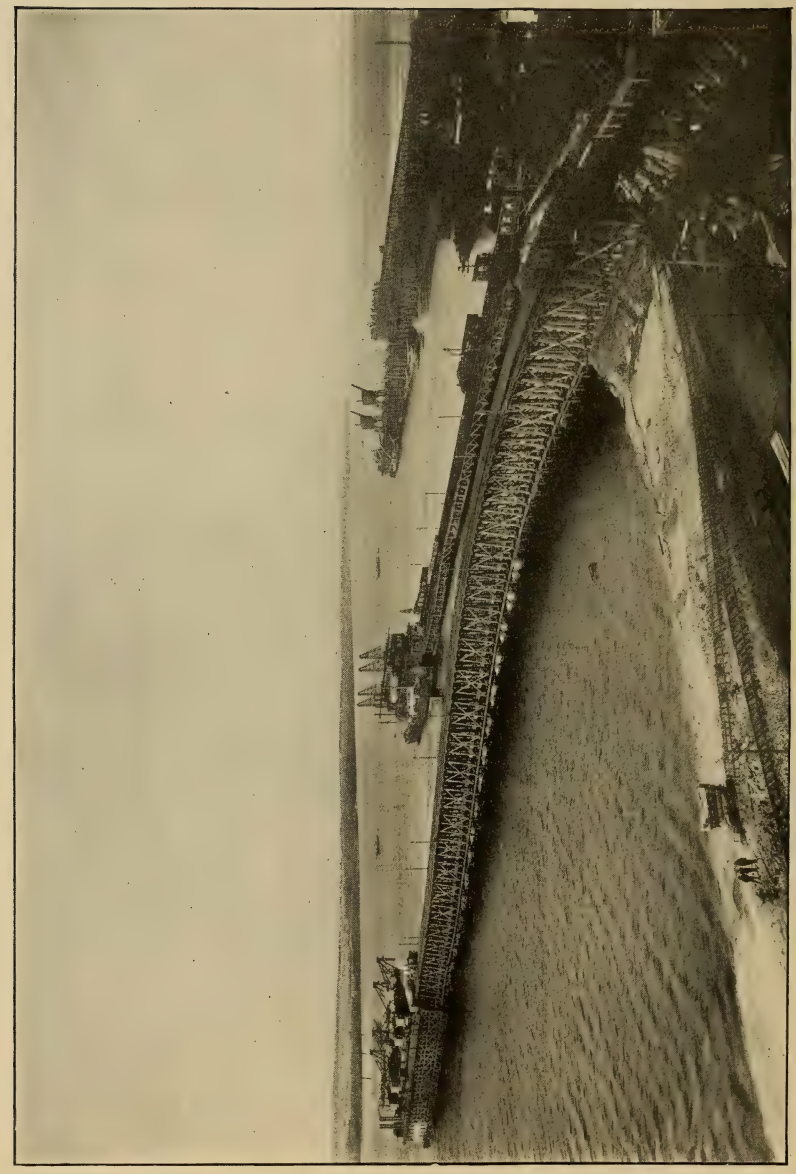


FIG. 3.—THE HIGH AND LOW-LEVEL PIERS. THEY ARE 100 FEET LONG. THE BINS ARE OF STEEL, AND ARE PROVIDED WITH SPOUTS FOR DELIVERY INTO THE SCALE CARS

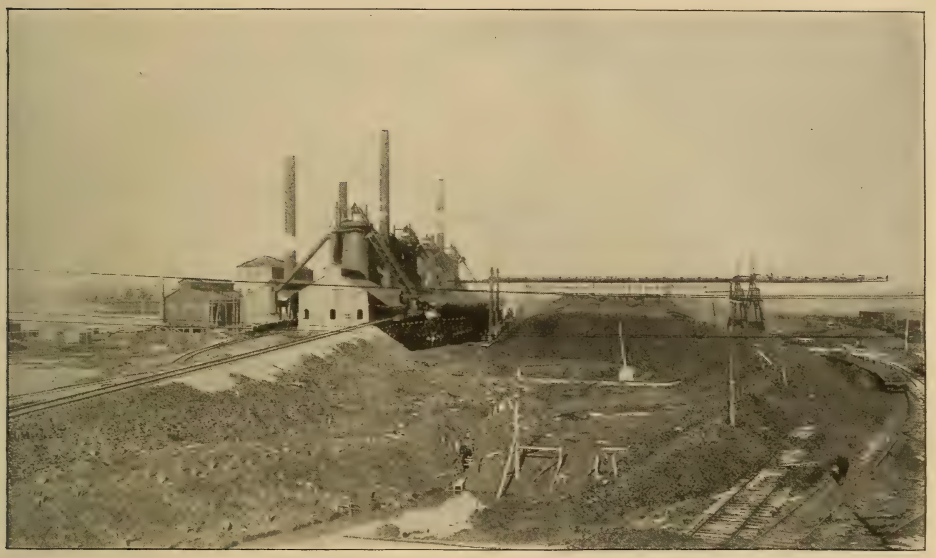


FIG. 4.—THE ORE YARD, EQUIPPED WITH BROWN HOISTS

from the port of Louisburg, on the South coast, twenty-two miles from Sydney as the crow flies, and connected with it by railway. As may be inferred from the foregoing, Sydney is in every sense a healthy climate. Ague and chills are unknown, and the usual fever diseases find scanty lodgment there.

Two years ago Sydney was a quiet little town of about three thousand inhabitants. To-day it has over ten thousand, and is rapidly growing. It has, so far, passed through its sudden awakening with credit. Over fifteen hundred houses have been built,—a large proportion of the better class; many miles of sewer and water pipe have been put down; fire-engines have been pur-

FIG. 5.—THE MACHINE SHOP AND FOUNDRY

FIG 6.—A PARTIAL VIEW OF THE WORKS OF

chased, and streets improved and macadamised. All that is done is done well, and, what is more, it is done honestly. The town developments are along more ambitious lines than generally apply in the States. British permanency and American speed have been crossed, and with good effect.

It has been an interesting study to note the reception by the local inhabitants of the many newcomers. Sydney is an old town,—a community of sturdy independence, of long-settled habits, and of intense, perhaps slightly fanatical, religious convictions. It has been suddenly invaded by the nondescript crowd that always accompanies the quick building of a steel plant,—a crowd in great part aliens. Sunday quiet that had been sacred in its observance has been violated; prohibition that had hitherto been real, at least somewhat changed; peace and comfort turned into work and turmoil. Such was Sydney's trial. They have met it well. In a broad-gauged, manly way they are studying how to adapt the past to the present; trying to hold on to what is good and right by weeding out what is useless of the past, but with an intent not to let the present run into license. And they will solve the problem. The new Sydney will be a desirable home and a city worthy of its destiny.

Here is located the large coal district, owned in almost its entirety by the Dominion Coal Company, Ltd. The coal property so controlled comprises 160 square miles of coal territory, all on tide water, with five workable seams, running from 6 to 10 feet in thickness. In composition the coal is highly bituminous, high in carbon, low in ash. Sulphur runs somewhat high for metallurgical purposes, but as a large part of this is in the form of pyrites, it is capable of successful washing. A general analysis will show about the following:—

Moisture	3.12	per cent.
Volatile combined matter	31.81	"
Fixed carbon	60.17	"
Sulphur	1.85	"
Ash	4.90	"

The coal can be washed down to about 1.20 per cent. sulphur and 3½ per cent. ash, which, in the retort oven, will give a coke containing a little more than 1 per cent. sulphur. The Dominion Coal Company, Ltd., is lifting an average of ten thousand tons a day the year round, and is now completing a

THE DOMINION IRON & STEEL COMPANY

new and large shaft that is expected to add about six thousand tons per day to its product. Such is the point at which the new works of the Dominion Iron & Steel Company are located.

The ingredients governing the manufacture of steel are coal, ore, limestone, and dolomite. The coal we have dealt with. The ore at present worked is a hematite obtained from Wabana, an island in Conception Bay, in Newfoundland. It exists in large quantities in a well-defined bed, running from 6 feet to 10 feet thick, and an average analysis shows that it contains from 50 per cent. to 52 per cent. iron and about 0.70 per cent. phosphorus. The mining is cheap, and the ore is economically transported by steamer from Wabana to Sydney, 402 miles The estimated cost of the ore, delivered at Sydney, was $1.25 a ton, but the company is already delivering the ore in the stock pile at a considerably lower figure.

The writer says "the ore at present worked" advisedly. The discovery of large bodies of ore in Canada, and the temptation of the extra bounty offered by the Canadian Government, render it more than likely that the Newfoundland deposit will soon become only auxiliary to a main supply that will be worked on the mainland proper, as already well-defined districts in Canada offer ore equally as cheap.

The limestone is obtained at a point in the beautiful Bras d'Or Lakes, called Marble Mountain. It is, as the name implies, a mountain of marble, and hence extremely pure as a limestone. Its average analysis shows:—

Silica	0.72 per cent.
Peroxide of iron	0 34 "
Alumina	0.24 "
Carbonate of lime	95.43 "
Carbonate of magnesia	3.03 "
Sulphur	0.048 "
Phosphorus	0.002 "

The extent of the deposit is practically unlimited. The limestone will be towed to Sydney in specially constructed barges,—a distance of under sixty miles,—at an almost nominal freight charge.

The dolomite is obtained from a point called George's River, only sixteen miles by railroad from the works. A typical analysis gives the following:—

Silica	0.66 per cent.
Alumina and peroxide of iron	1.80 "
Carbonate of lime	53.89 "
Carbonate of magnesia	43.40 "
Sulphur	0.055 "
Phosphorus	0.09 "

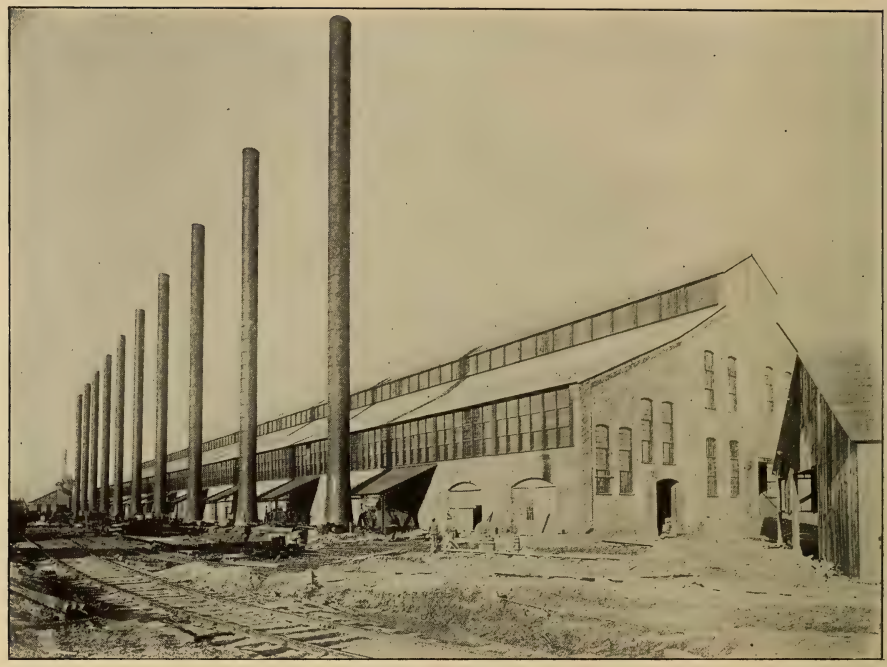


FIG. 7.—THE OPEN-HEARTH PLANT

FIG. 8.—AN INTERIOR VIEW

The natural opportunities thus present themselves as an abundant and cheap supply of ore, coal, limestone, and dolomite, assembled at a commodious and safe water terminal. The result was the foundation of the Dominion Iron & Steel Company, organised to manufacture steel by the basic open-hearth process. The plant was commenced in the late fall of 1899, and was making steel in January, 1902. The several blast furnaces are in operation, and have made, at this writing, over 110,000 tons of pig metal, which has been shipped to over three hundred customers, covering practically all of

FIG. 9.—THE PIG IRON CASTING MACHINE

developed Canada, the whole Atlantic seaboard of the United States, the largest part of England, and, to some extent, Germany. Its product has found a resting place in Europe during a time of depression, and in the United States, in spite of a prohibitive tariff, and it has given entire satisfaction.

The plant is the most modern of its kind. The raw material is received at a high level pier, Fig. 3, and is delivered on this level to the blast furnace bins. From these bins, shown in Fig. 13, it is either delivered directly to the skip car, thence automatically to the furnace top, or, if not needed there, to the stock yard for future use. Its delivery to the stock yard, and, later, its transfer from the stock yard back to the furnace bins, is controlled by three Brown hoists, electrically driven. Of the ore yard and hoists a view is given on page 281.

The coke is made in Otto-Hoffman retort ovens, in which all the by-products, gas, coal tar, and ammonia, are saved and utilised. The coke is received on a wharf or level floor, and is there quenched, being subsequently loaded into hopper cars for delivery to the blast furnace bins. It is proposed to erect chemical works to utilise to the utmost the various ingredients resulting from the above components. The limestone and dolomite pass through similar bin mechanism as that used for the ore, and in all of this handling of raw material the cost has been brought down to exceedingly low figures.

The gas from the blast furnaces offers an excess over that needed for their operation. This excess is put into electricity in an electric power house, current being led to almost every part of the works.

The boiler house of the blast furnaces, containing 8000 horse-power of Babcock & Wilcox boilers, are gas fed, and call for the employment of but few men.

FIG. 10.—THE COKE PLANT

The blowing engines, shown in Fig. 14, are of the Kennedy type, built by the Allis-Chalmers Company, of Chicago, and are compound condensing. They are five in number, one for each furnace and one as a spare, and are estimated as capable of delivering 50,000 cubic feet of air per minute each.

The metal from the blast furnaces is conducted directly to the open-hearth plant, which comprises ten fifty-ton tilting furnaces. These furnaces are the heaviest so far constructed anywhere. The building in which they are housed, shown in Fig. 7, is of brick with a tile roof, as are all of the other buildings. The furnaces are served by two seventy-five-ton cranes. Every available labour-saving device has been adopted. The regenerators are of unusual size, in order to secure the greatest fuel economy. The charging of the furnaces is controlled by Wellman-Seaver charging machines, and the casting of the steel ingots is done in cars. Should an excess of pig iron exist at any time, it is conducted to a pig casting machine, Fig. 9, where it is mechanically transformed into pigs, the hot metal being lifted in its ladle by cranes in the building and tilted so that the metal flows into a travelling chain of moulds, which, passing through water, deliver the cooled pigs automatically at the other end into railway cars. Adjoining the open-hearth plant is a gasometer capable of holding 1,000,000 feet of gas. In this is stored the surplus gas from the coke ovens, which is the fuel used for the open-hearth furnaces. The gasometer acts as a regulator.

From the open-hearth plant the steel ingots are passed through the usual stripping building and thence to the blooming mill, at which point the present construction ends, so far as finished work is concerned. But already the foundations are well along for a rail and billet mill, which, like all the rest of the plant, is to be of the most modern type. In front of the blooming mill, and in consecutive rotation, are to be the first roughing, second roughing, and finishing trains, and the piece will pass directly from one to the other on its path to the finished rail, eventually going to the hot-bed and thence to the finishing building, which will be furnished with the most complete machinery, including rotary planers for giving an accurate finish to the ends of the rails.

As Sydney is somewhat distant from neighbouring cities, the plant has been provided with an ample machine shop and foundry, shown in Fig. 5. The tools in the machine shop are of an assortment and variety that, at a pinch, would be capable of constructing anything in the plant, and the foundry is capable of casting the heaviest piece of

steel or iron likely to be needed. This plant is provided with pattern shops, carpenter shop, tin shop, paint shop,—indeed, every accessory needed for either repair or construction. It is today one of the largest in Canada.

The water supply is obtained from Sydney River, four and one-half miles from the works, affording a reservoir that contains fifteen hundred million gallons of pure water. It is fed by a watershed that will deliver to it an average of fifteen million gallons per day.

All the finished material is shipped either directly by rail, or by water. In the latter event it is shipped by the low

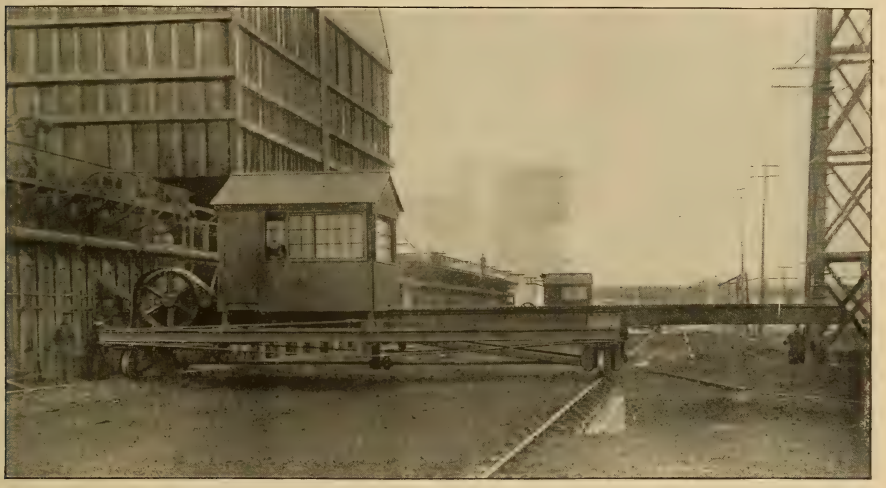


FIG. 11.—THE COKE IS MECHANICALLY PUSHED OUT OF THE OVENS BY ELECTRIC PUSHERS

FIG. 12.—AFTERWARDS IT IS QUENCHED

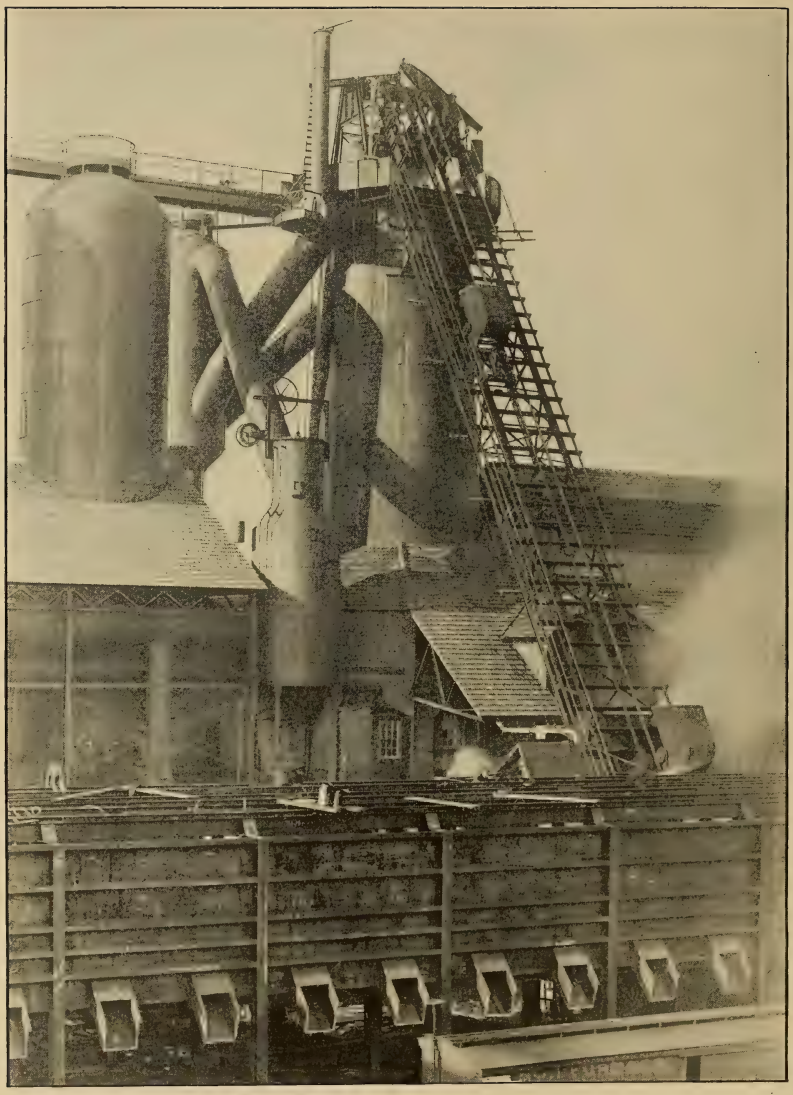


FIG. 13.—ONE OF THE BLAST FURNACES WITH THE BINS FOR THE RAW MATERIALS

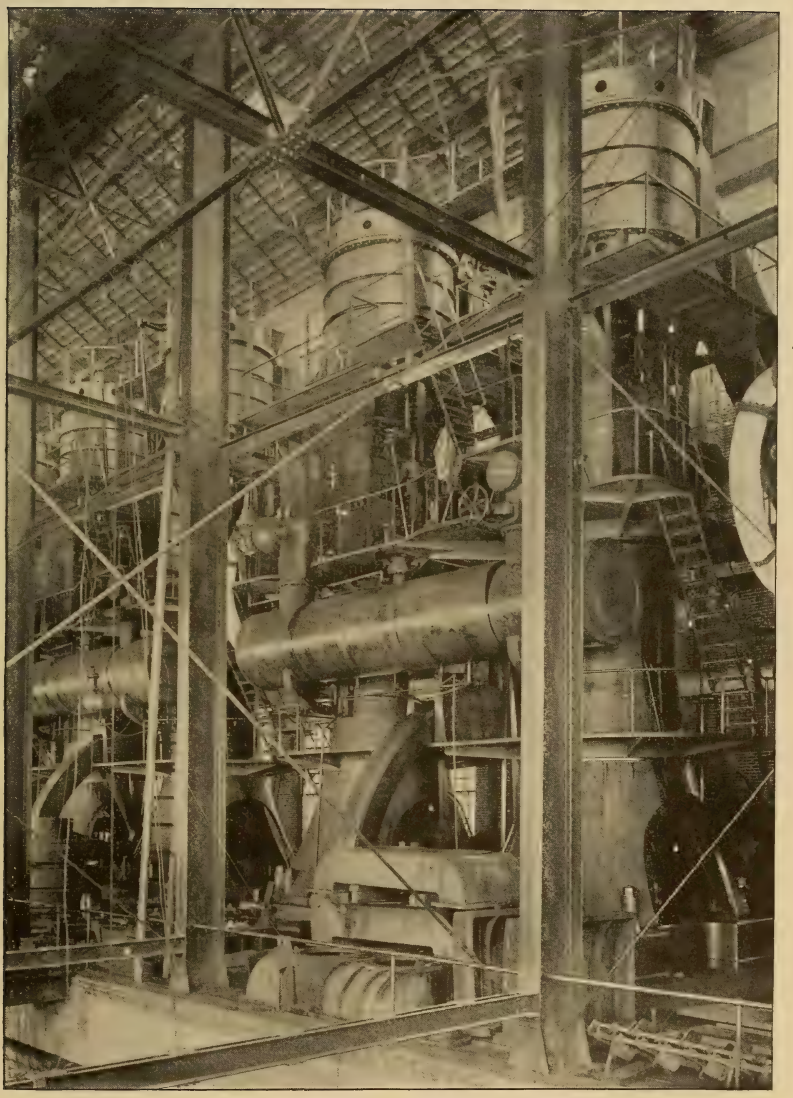


FIG. 14.—THE BLOWING ENGINES. EACH DELIVERS 50,000 CUBIC FEET OF AIR PER MINUTE

pier, known as No. 1 Pier, shown in Fig. 1.

Such is a brief description of Canada's latest contribution to the steel business. It is, in proportion to her population, a noteworthy and bold effort, and the subscribers to the enterprise have evidenced in their liberality and patience a determination to succeed that is something which is to be reckoned with. While the enterprise does not possess the artificially high market of the United States, resulting from a high protective tariff, it does not need it. While it has to pay freight to reach the European markets, it can, and does, assemble at tide-water materials for making steel cheaper than they can be assembled anywhere in the world, and so can afford to pay it. It is located nearer to foreign markets than any competing points.

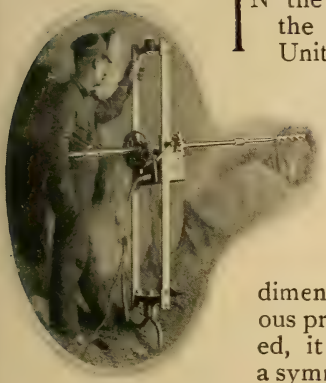
The works can deliver to any point in the British colonies, South America, or Asia as cheaply as any of the present exporting countries, and as it can deliver to them at a lower price than they can manufacture, its rightful heritage is to feed their foreign markets.

While of modest tonnage, the company controls in its own right all that is controlled, for example, by the United States Steel Corporation. It has its own ore mines and its own limestone supply, and it has an option in the coal mines of the Dominion Coal Company, Ltd. Perhaps the only drawback is its distance from a thickly developed supply of skilled labour; but even in this matter it is well situated. The trend of emigration from Europe to the West can as well pass on its way via Sydney as it can directly via New York, and skilled labour from abroad will be quick to learn this fact; indeed, it is already learning it. As all the various supplies of the company are on tide-water, it is in control of its own transportation.

COAL CUTTING MACHINERY

WITH SPECIAL REFERENCE TO AMERICAN PRACTICE

By Edward W. Parker, Former Statistician of the United States Geological Survey



IN the calendar year 1899 the coal mines of the United States turned out a product amounting to 226,553,564 long tons of 2240 pounds, equivalent to 253,739,992 short tons of 2000 pounds. That some idea of the dimensions of this enormous product may be obtained, it may be stated that a symmetrical column constructed of it, and having a base 1000 feet square (equal to the height of the Eiffel tower), would reach a height of 6285 feet, or a little over 1.2 miles; its top (with the base at sea level) would be within 8 feet of the highest point on Mt. Washington, N. H.; it would be more than eleven times the height of Washington monument, in the city of Washington, and more than six and one-quarter times as high as the Eiffel tower. Taken from a vein of coal having an average thickness of 6 feet, the territory excavated would have an area of 24,047 acres, or about 37½ square miles.

The output in 1899 made the United States the leading coal producing country of the world, with 32 per cent. of the world's total product. Prior to 1899 Great Britain held first place, her product in 1898 exceeding that of the United States by over 6,300,000 short tons, while the American output in 1899 was the greater by 7,240,000 tons. If the reports of the approaching exhaustion of Great Britain's supply have any foundation in fact, it is not probable that the United States will be deposed from the position she now holds in relation to the world's supply of mineral fuel.

The value of the coal product in 1899 was $256,077,434, approximately one-fourth of the total value of the mineral products of the United States for that year.

Anyone at all familiar with the extraordinary industrial condition which prevailed throughout the United States in 1899 is aware that the largely augmented coal production in that year was due to the demand made upon the coal mines by the manufacturing and transportation interests of the country. But everyone is not aware how the operators had been prepared by a period of adverse conditions extending over more than ten years to meet this unexpected and unprecedented demand. From 1887 until 1898, and particularly during the business depression from 1893 to 1896, coal operators were contending with a continued overproduction and constantly declining prices. This was especially true in regard to the production of bituminous coal. Anthracite coal, having become almost entirely a domestic fuel, is not so readily affected by changing industrial conditions; and, moreover, its producing area being comparatively small and the industry in the hands of relatively few and powerful interests, the production and prices are more easily controlled.

Such is not the case in bituminous circles. Scattered over vast and widely separated areas and with the various competitive fields (many of them considerably over-developed) struggling for markets for their output, the record for the twelve years preceding 1899

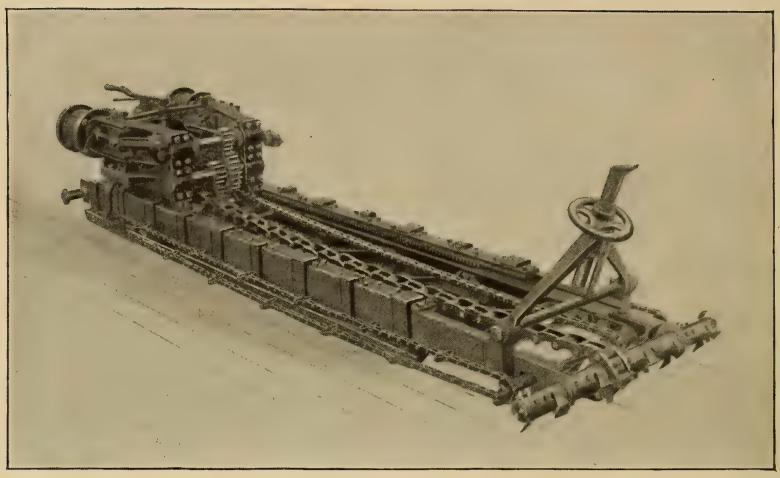


FIG. 1.—A CUTTER BAR MACHINE WORKED BY COMPRESSED AIR MOTORS, MADE BY THE JEFFREY MFG. CO., COLUMBUS, OHIO, U. S. A., AN EARLY TYPE

was, to say the least, one of a very unsatisfactory nature. In 1887 the average price for all of the bituminous coal mined in the United States was $1.12 per short ton; in 1888 the average price was 80 cents, a decline of 32 cents, or 28.66 per cent. During this period the price of labour had not materially changed, and bituminous operators have practically been forced to the adoption of other methods for cheapening the cost of production.

This has been accomplished, in part, by the investment of large sums of money in improved systems of haulage, the combining of large interests under one management, and by other judicious economies; but in no other way has so much been accomplished as in the development of the use of machines for mining the coal. It has happened that when the sudden impetus was given to the American coal mining industry in 1899 by the industrial revival of that year, many of the larger operations were found equipped with mechanical appliances which enabled them to materially expand their output with comparatively little addition to their pay rolls, and the coal mining industry presents no more interesting feature than that shown in the fact that the conditions brought about by the period of industrial depression were made effective in taking care of the enormous trade developed by the active times of 1899.

In the preparation of the report on the production of coal in 1896 for the annual volume on "Mineral Resources of the United States," published as a part of the eighteenth annual report of the United States Geological Survey, the writer made the first attempt to collect the statistics of the production of coal by machinery, coupling the inquiries with a request for records of the production in 1891. The statistics of machine-mined coal have been continued in subsequent reports. The results showed that during the year 1891 there were in use in the bituminous coal mines of the United States a total of 545 undercutting machines, and that 6,211,732 tons, or 6.66 per cent. of the total bituminous product of the year, had been machine-mined In 1896 the number of machines in use had increased to 1446, and the machine-mined product to 16,424,932 tons, or 14.17 per cent. of the total, while the statistics for 1899 show that 3125 machines produced 43,963,933 tons, or 23 per cent. of the total product How this production was distributed among the various States may be seen from the tabulated statement by the author on page 295,

taken from the report on the production of coal in 1900.*

The average number of tons of coal produced per man employed in 1891 was 573, and the average tonnage per man per day was 2.57. In 1899 713.3 tons of coal were mined for each man employed, and the average tonnage per man per day was 3.05. In arriving at these averages the number of men employed include all those employed in and about the mines. If the miners only were included, a greater difference would be shown between the two years, as the employment of mining machines increases the number of "day" men, particularly for loading cars. In pick mining the miner and his helper load the cars themselves; in machine mining the helper is employed in keeping the cut clear of slack, and the loading is done by other men, two or three being employed for each machine.

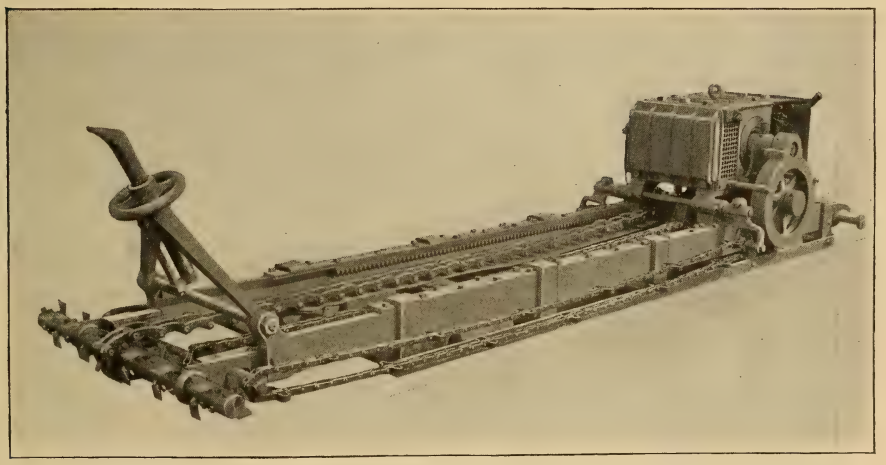


FIG. 2.—A JEFFREY ELECTRICALLY-DRIVEN CUTTER BAR MACHINE. THE FIRST ELECTRIC COAL CUTTER MADE. BOTH THIS AND THE COMPRESSED AIR MACHINE, SHOWN IN FIG. 1, ARE OBSOLETE, BUT A LARGE NUMBER OF THEM ARE STILL IN USE

KINDS OF MACHINES IN USE

The two general types of machines in most common use in the coal mines of the United States may be classed under the heads of "pick" or "punching" machines, and the "chain breast," although a few "longwall" machines are in successful use in some of the thin seams of the Western States. The method of mining in America is usually some adaptation of the "pillar-and-room" or "stall-and-pillar" system, and most of the longwall machines made in the United States are shipped to Europe where that system of mining is generally practiced. There are, in the United States, seven extensive manufacturing establishments making a specialty of coal mining machinery. Three of these make pick machines and four manufacture chain cutting machines. The principal pick machines in use are the Harrison, manufactured by the George. D Whitcomb Company, of Chicago, Ill.; the Sullivan, made by the Sullivan Machinery Company, Chicago, Ill.; and the Ingersoll, made by the Ingersoll-Sergeant Drill Company. of New York. The chain machines are the products of the Jeffrey Manufacturing Company, of Columbus, Ohio; the Goodman Manufacturing Company, manufacturers of the "Independent" or "Link-Belt" machine formerly made by the Link-Belt Machinery Company; the Morgan-Gardner Electric Company; and the Morgan-Standard Company, all of Chicago, Ill.

These types of mining machines have

* Annual Report of the United States Geological Survey.

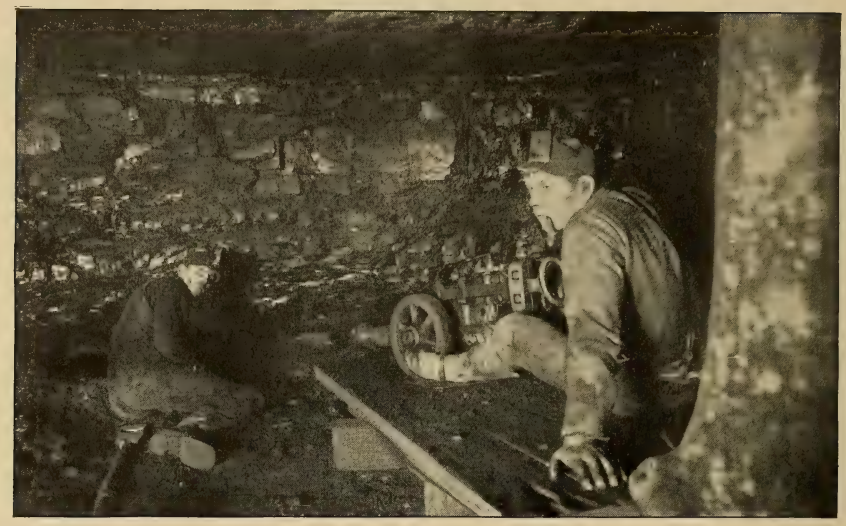


FIG. 3.—A HARRISON PICK MACHINE MADE BY THE GEO. D. WHITCOMB CO., CHICAGO

FIG. 4.—A HARRISON MACHINE MOUNTED FOR A SHEARING CUT

been brought to such a degree of efficiency that, it is safe to say, there are comparatively few bituminous coal mines, operated upon an extensive scale, that could not with advantage be equipped with mining machines. There is but one adverse condition that has not been successfully surmounted, and that is the inclination of the vein when the dip exceeds 12° or 15°. Some of the pick machines have been used in mines where the inclination was as much as 23°; but the work was slow and difficult, and it was only from the fact that the price of labour was high that the machine was able to compete with it. The trouble does not lie so much in the actual cutting, but in the difficulty of moving the

BITUMINOUS COAL MINED BY MACHINES IN THE UNITED STATES IN 1891, 1896 AND 1900

State	Number of Firms Using Machines			Number of Machines in Use		
	1891	1896	1900	1891	1896	1900
Alabama	--	----	4	----	----	54
Alaska	--	1	----	----	6	(a)
Arkansas	--	1	2	----	14	20
Colorado	1	6	5	20	34	90
Illinois	16	21	43	241	307	430
Indiana	3	11	19	47	186	254
Indian Territory	--	3	4	----	56	58
Iowa	2	5	4	9	45	40
Kansas	--	----	1	----	----	3
Kentucky	--	----	21	----	----	239
Maryland	--	----	2	----	----	10
Michigan	--	----	6	----	----	33
Missouri	--	1	5	----	4	15
Montana	--	3	5	----	62	81
New Mexico	--	----	2	----	----	21
North Dakota	--	1	3	----	1	7
Ohio	19	31	58	114	209	341
Pennsylvania	7	41	73	72	454	1,786
Tennessee	--	----	3	----	----	18
Texas	--	----	----	----	----	----
Utah	--	1	----	----	1	----
Virginia	--	----	3	----	----	9
Washington	--	1	1	----	3	2
West Virginia	1	7	55	8	25	327
Wyoming	2	2	4	34	39	69
Total	51	136	323	545	1,446	3,907

a Not reported.

State	Total Tonnage		
	1891	1896	1900
Alabama	----------	----------	8,394,275
Alaska	----------	15,233	----------
Arkansas	----------	675,374	1,497,945
Colorado	3,512,632	3,112,400	5,244,364
Illinois	15,660,698	19,786,626	25,767,981
Indiana	2,973,474	3,905,779	6,484,086
Indian Territory	----------	1,366,646	1,922,298
Iowa	3,825,4 5	3,954,028	5,202,939
Kansas	----------	----------	4,467,870
Kentucky	----------	----------	5,328,964
Maryland	----------	----------	4,024,688
Michigan	----------	----------	849,475
Missouri	----------	2,331,542	3,540,103
Montana	----------	1,543,445	1,661,775
New Mexico	----------	----------	1,299,299
North Dakota	----------	78,050	129,883
Ohio	12,868 633	12,875,202	18,988,150
Pennsylvania	42,788,490	49,557,453	79,842,326
Tennessee	----------	----------	3,708,562
Texas	----------	----------	----------
Utah	----------	418,627	----------
Virginia	----------	----------	2,393,754
Washington	----------	1,195,504	2,474,093
West Virginia	9,220,665	12,876,296	22,647,207
Wyoming	2,327,841	2,229,624	4,014,602
Total	93,177,978	115,921,828	209,864,639

State	Number of Tons Mined by Machines		
	1891	1896	1900
Alabama	----------	----------	370,150
Alaska	----------	15,232	(a)
Arkansas	----------	21,094	219,085
Colorado	284,646	318 172	756,025
Illinois	3,027,305	3,871,410	5,083,594
Indiana	212,830	964,378	1,774,045
Indian Territory	----------	191,585	239,424
Iowa	41,540	84,556	132,757
Kansas	----------	----------	46,164
Kentucky	----------	----------	2,339,944
Maryland	----------	----------	138,014
Michigan	----------	----------	191,577
Missouri	----------	47,827	110,036
Montana	----------	579,414	1,045,115
New Mexico	----------	----------	112,000
North Dakota	----------	15,000	33,965
Ohio	1,654,081	3,368,349	8,835,743
Pennsylvania	431,440	6,092,644	26,867,053
Tennessee	----------	----------	176,872
Texas	----------	----------	----------
Utah	----------	760	----------
Virginia	----------	----------	231,269
Washington	----------	3,920	10,000
West Virginia	205,784	430,944	3,418,377
Wyoming	354,106	419,647	653,314
Total	6,211,732	16,424,932	52,790.523

a Not reported.

State	Percentage of Total Product Mined by Machines		
	1891	1836	1900
Alabama	--------	--------	4.41
Alaska	--------	100.00	---
Arkansas	--------	3.12	14.82
Colorado	8.10	10.22	14.42
Illinois	19.33	19.57	19.73
Indiana	7.16	24.69	27.36
Indian Territory	--------	14.02	12.46
Iowa	1.09	2.14	2.55
Kansas	--------	--------	1.03
Kentucky	--------	--------	43.91
Maryland	--------	--------	3.43
Michigan	--------	--------	22.55
Missouri	--------	2.56	3.11
Montana	--------	37.54	62.89
New Mexico	--------	--------	8.62
North Dakota	--------	19.22	26.15
Ohio	12.85	26.16	46.53
Pennsylvania	1.01	12.29	33.65
Tennessee	--------	--------	4.77
Texas	--------	--------	--------
Utah	--------	0.18	--------
Virginia	--------	--------	9.66
Washington	--------	0.33	0.40
West Virginia	2.23	3.35	15.09
Wyoming	15.21	18.82	16.27
Average	6.66	14.17	25.15

machines from place to place. Manufacturers do not care to run the risk of failing, and prefer not to install machines where the dip exceeds, say, 14°. By the use of self-propelling trucks it has been found possible to use chain machines in mines having this amount of inclination from the horizontal; but that is about the maximum. The self-propelling truck also enables the chain machine to be used in mines where the seam is so thin that it would be otherwise impossible to draw the machine or move it up to the face of coal, as neither horses nor mules could go into the room unless some of the floor were taken up or the top taken down.

All of the pick machines in successful operation at the present time are driven by compressed air, although the Morgan-Gardner Electric Company claims to have developed an electrically-

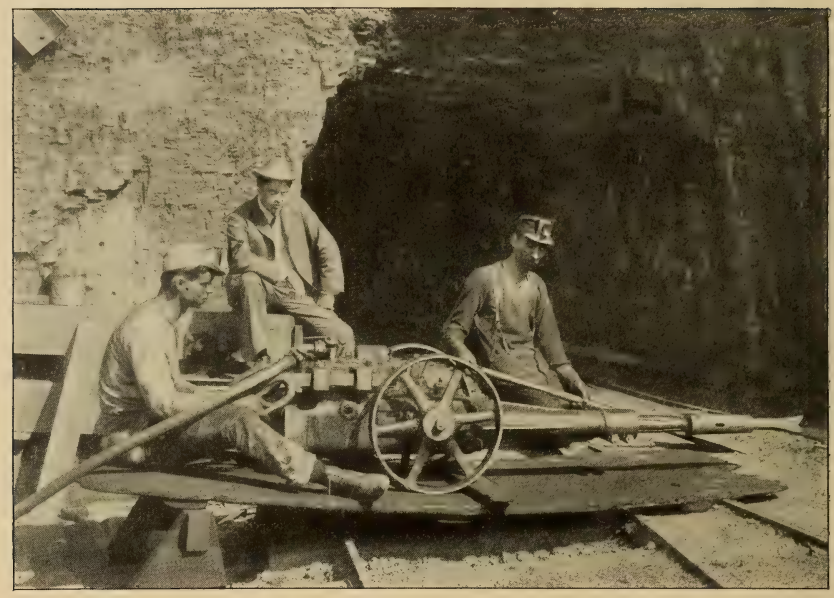


FIG. 5.—A PICK MACHINE MADE BY THE INGERSOLL-SERGEANT DRILL CO., NEW YORK AND LONDON

driven pick machine which has overcome the mechanical difficulties heretofore effective against the use of any other than an air-driven pick machine. Most of the chain machines and all of the few longwall machines in American use employ electricity as a motive power. In some of the longwall machines of British make, illustrated by a few examples later on, compressed air supplies the power. In some mines where gas is present in dangerous proportions, and is apt to be exploded by an electric spark, or where other conditions are against electric installation, chain machines operated by compressed air are in use. Out of 1106 chain machines in use in 1899 about 10 per cent. were propelled by compressed air. One of the principal objections offered to the use of air for a chain machine is the low temperature produced about the legs of the operative by the expanding air from the exhaust. This cold is sufficient to cover the exhaust pipe with frost and to produce rheumatism in the miners' legs.

From a detailed statement of the number of machines of each make in use in the bituminous coal mines of the United States in 1899, it appears that the pick or punching machines exceed in number, there being 1997 out of a total of 3125. Of the remainder, 1106 were chain breast machines and 22 longwall machines. The last are used to any extent only in the States west of the Mississippi River,—Iowa, Kansas, and Missouri. Alabama had two in use in 1899.

Although the first patent granted in the United States for a coal under-cutting machine was issued in 1858,* more than twenty years had elapsed before the possibility of mining coal by mechanical methods had been successfully demonstrated. The United States Patent Office files are crowded with descriptions of devices invented, many not worth in themselves the paper on which they are printed, but all probably marking steps in the development of the present successful machines. The distinction of having invented the first successful mining machine is probably

* Patent No. 21,908 was issued to Elisha Simkins, of Allegheny, Pa., in 1858, since which time nearly 500 other patents on mining machines or improvements thereon have been granted.

due to Francis M. Lechner, of Columbus, Ohio, to whom, in January, 1876, was granted a patent on what was known as the rotary-bar breast machine. Nearly two years later, on Christmas Day, 1877, a patent was issued to J. W. Harrison on a pick or punching machine. The latter machine improved by later inventions, and by the strengthening and alterations of parts where weakness was developed, is similar in style to-day to the original Harrison machine, whereas the rotary bar has become obsolete and is no longer made. Lechner, however, was the inventor also of the first chain machine which was the successor to the rotary bar.

The two patents mentioned were issued, one in 1876 and one in 1877, but it was not until about 1880 that they may be said to have come into actual use. Much time and money were lost in overcoming difficulties that unexpectedly developed, and both operators and manufacturers were often almost hopelessly discouraged. It was soon shown that a machine capable of doing good work on clean, soft coal was a very uncertain factor in harder coal, or when a band of sulphur in the form of pyrite or other hard substance was encountered. Lack of proper control when the "load" was suddenly taken away caused the machines to race with disastrous results. These defects were overcome by the strengthening of parts where weakness was developed; by providing air-cushioning for taking up the shock in machines of the pick type when the cutter missed the coal; and by better control, sometimes automatic, of the motive power.

Still another difficulty which the machine had to face was the opposition of the labour organisations. The miner, seeing in it a possible supplanter of his labour, was under no incentive to treat it with care and tenderness, nor did he. From the fact that in the eleven years from 1880 to 1891 the number of mining machines in use amounted to only 545, and the machine-mined tonnage in 1891 was only a little over 6 000,000 tons, it is evident operators were not any too quickly impressed with the idea that mining machines were economical; whereas the increase to 1446 machines in 1896 and 3907 in 1900, with a machine-mined product respectively of 16,424,932 short tons and 52,790,523 short tons, indicates a rapid development during the latter period.

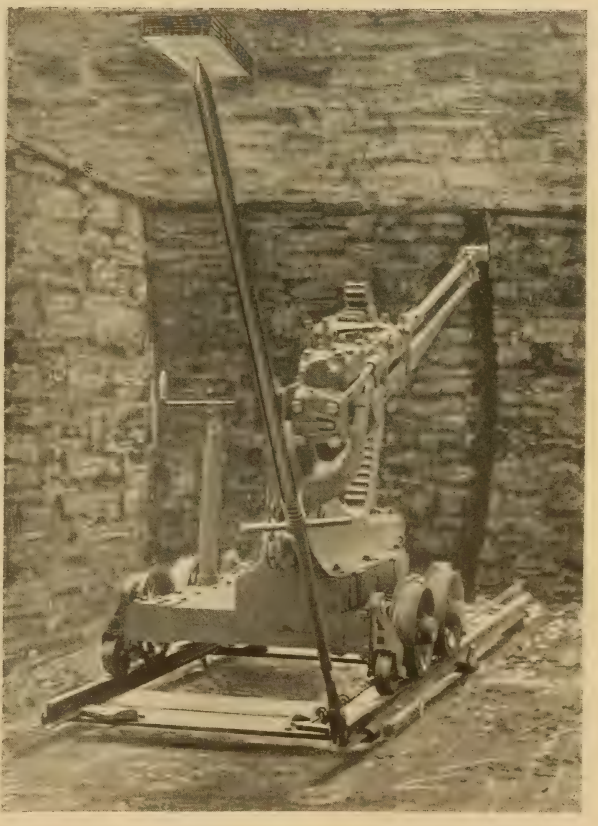


FIG.6.—A SHEARING PICK MACHINE MADE BY THE SULLIVAN MACHINERY CO., CHICAGO. THIS VIEW CLEARLY SHOWS THE CHARACTER OF THE CUT MADE BY THE MACHINE

FIG. 8.—A PICK MACHINE MADE BY THE SULLIVAN MACHINERY COMPANY, CHICAGO

THE ROTARY BAR MACHINE

As already stated, the rotary bar machine is now obsolete, and its manufacture has been discontinued But as it was the first successful coal mining machine on the market, and possesses an historic interest in the development of mechanical mining, a description of it is here given. The rotary bar was the pioneer product of the Jeffrey Manufacturing Company, the first machine having been placed upon the market in 1876. It was designed originally to be operated by compressed air. The engine on this machine was upright, and consisted of two cylinders, solid with the outside frame of the machine: and the part carrying the cutter, or bits, was fed into the coal by means of a screw working through a movable nut. This nut formed part of the inside frame, or that portion of the machine to which the cutter bar was attached. The cutter bar was rotated by means of an endless chain, driven by sprockets attached to the main driving shaft of the machine. The manufacturers frankly admit that the first machines of this type were crudely constructed, very light, and purely experimental. They were put to work however, and although found to be capable of cutting very soft coal, they quickly went to pieces when they encountered harder bituminous coals, or any of the impurities which are commonly found in bituminous veins. Immense amounts of money and patience were expended on the early type of machine, and the first ones built were kept constantly on the road between the mines and the shop, first one part failing and being strengthened, and then another giving way.

While the process of strengthening was going on new features were being developed. The machine was made heavier; the cylinders were changed from the vertical to the horizontal position, and from the outside, or stationary part, of the machine to the inside or movable frame, so that the motor moved forward as the cutter was fed into the coal; the feeding arrangement was changed from the screw-and-nut to the rack-and-pinion type; and so on, until an air-driven rotary-bar machine had been developed which impressed coal operators favourably. Before this was accomplished, however, a number of the earlier types of air rotary-bar machines had been put to work, and to a degree, successfully; but their field was confined to the very softest coals, in which sulphur (pyrite), clay veins, etc., were not encountered. Strengthening and improving the machines made it possible to attack harder coals, and in each year after the first machine was built coal which the year before the builders would have hesitated to attack was successfully mined.

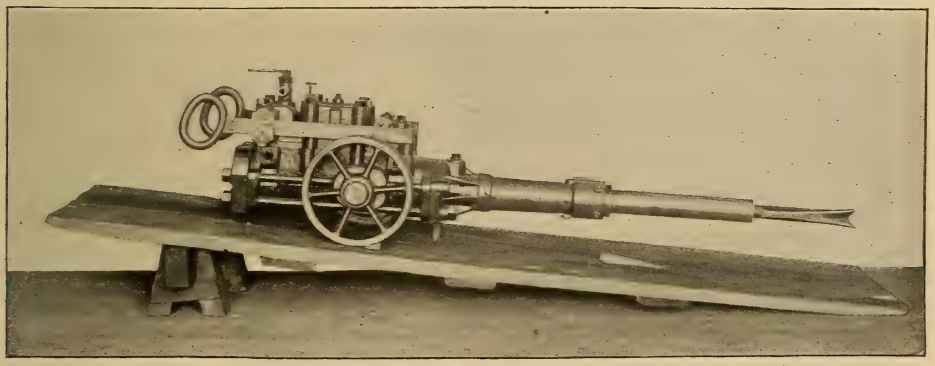


FIG. 7.—THE LATEST TYPE OF HARRISON PICK MACHINE

Between 1880 and 1890 the engineers of the Jeffrey Company, thus engaged in constant work on the air rotary-bar

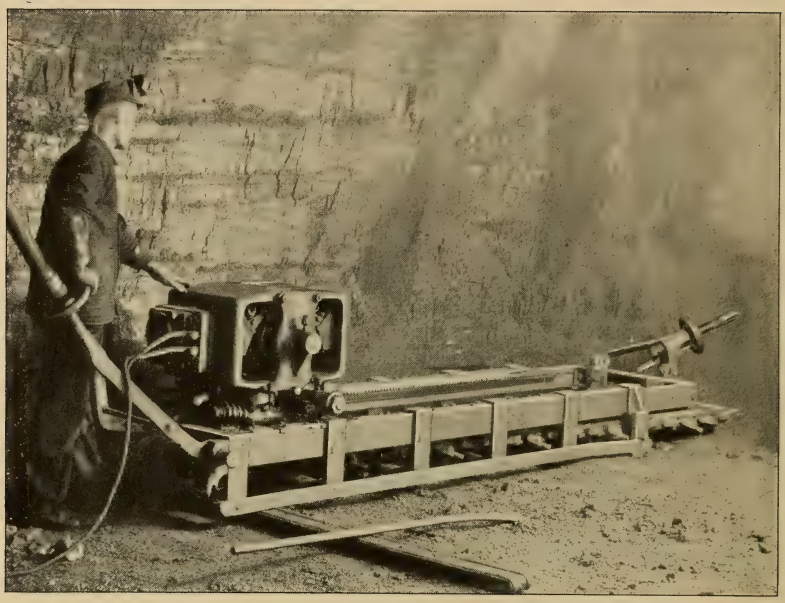


FIG. 9.—A JEFFREY ELECTRIC CHAIN MACHINE READY FOR A CUT

machine, naturally had their attention called to the possibility of substituting an electric motor for the air-engine on the machine, and the problem had to be solved of developing a motor which would be practical for mine use. Many persons thoroughly conversant with coal-mining machinery discouraged the attempt, saying that it was simply throwing away money and wasting power, because an electric motor working in a coal mine where there was a constant dripping of water from the roof, where the bottom was wet and muddy, and where there was a terrible dust, made by the cutting of the machine, would not prove practical; but it is with a good deal of gratification that the Jeffrey Company is able to point to-day to the very first electric coal-mining machine built by it, which is cutting coal every day on which the mine in which it is used is running. This machine is shown in Fig. 2.

Little change was made in the mechanical arrangement of the rotary-bar machine when the electric motor was attached to it, but immediately after it had been shown that a rotary-bar machine could be operated successfully by electricity, there was an added interest by mine owners in mechanical means of getting coal. The electric power recommended itself, at the same time, for other purposes, such as the running of fans, hoists, and other machinery.

Before long the rotary-bar type of coal-cutter gave place to a still more successful machine. In its time, however, it had done good service, and some of the rotary-bar machines are still at work. But that it is a "back number" was demonstrated to the writer's satisfaction when, not long ago, he was shown several of these machines that had never been in use lying on the scrap heap at the makers' works.

PICK MACHINES

The general style of the pick or punching machine is essentially the same as that of twenty years ago, and the several makes differ only in unimportant details of construction for which the manufacturers make special claims of superiority. The machines have, of course, undergone much improvement since the first ones were placed on the market. Parts where weakness or other faults developed have been strength-

ened and altered, but the principal improvements have been in the air-cushion device for taking up the shock of the blow when the pick misses the coal, and the automatic throttling of the air supply at the same time. These are described more in detail later on in connection with the discussion of each machine.

The method of attacking the coal by the use of the pick machine is as follows:—The runner sits behind the machine, which is set upon an inclined platform, the angle of which holds the machine to the coal. The blow is struck in much the same way as the outward stroke is give to the piston-rod of an engine, except that compressed air, instead of steam, is the motive force. A shallow hole is first cut in the face of the coal, even with the floor. A few blows just above the hole break down enough coal and clear a way for the runner to deepen the original cut. He works his machine backward and forward on the platform along the face of the coal, the work being comparatively easy as soon as the first cut has been made to a sufficient depth. The runner uses a block attached to the sole of his shoe, to "chock" the wheels of the machine against the effects of the recoil from the blow. This has been found much more satisfactory than using a stone or block of wood, ratchet-wheel or other independent brace, as the runner receives little, if any, punishment, and has better control and is more in touch with his machine all the time.

The platform upon which he operates has about the same width as the cut intended to be made, and can be made in duplicate, so that when he is near the end of one cut his helper may place the other section beside it, and the machine may be moved from one to the other with little loss of time. As a usual thing, however, only one platform is used in a room. The helper is also expected to keep the cut as free as possible from the slack and small coal made in the cutting, so that, once placed in position, the runner has little to do except to manipulate and shift his machine, until the face is under-cut entirely across the room. The machine is then removed to another room and the first one is shot down. One of the advan-

FIG. 10.—AN ELECTRIC CHAIN MACHINE MADE BY THE MORGAN-GARDNER ELECTRIC CO., CHICAGO

FIG. II.—DRILLING FOR A BLAST

tages claimed for the pick machine is that, as the cut is V-shaped, with the wider part at the front, the coal will shoot down more perfectly, and does not have to be pulled down with a pick after the shot. Another admitted advantage of the pick machine is that it may be used in mines where conditions of roof and floor will not permit the introduction of the chain breast machine.

It is in many instances necessary to bring the timbering up to within 3 or 4 feet of the face of the coal, in which case the use of a chain machine, requiring 10 or 12 feet of clear space between the face of the coal and the supports of the roof, is manifestly impossible. In other cases, such as the frequent occurrence in the bottom of the coal of pyrite or other hard materials, which would break the bits of a chain machine, if not the machine itself, the pick machine has the advantage, as the runner is able to cut around the obstruction instead of being obliged to cut through it. Another advantage claimed for this type of machine (but which applies also with equal force to the chain-breast or longwall machines driven by compressed air) is that, in mines where the quantity of gas is so great that safety-lamps have to be employed, the danger of explosion, which might be caused by an electric spark from the motor, is obviated.

Figs. 3 to 6 are illustrations taken from photographs made by flashlight underground and show different views of the pick machines at work. Figs. 3 and 4 show two views of a Harrison machine at work. Fig. 5 shows an Ingersoll-Sergeant machine and Fig. 6 shows a Sullivan shearing pick machine and the character of a cut made by it.

The Harrison machine, now manufactured by the George D. Whitcomb Company, of Chicago, is unquestionably the pioneer machine of the pick type, and was one of the first to demonstrate successfully the possibility of substituting mechanical methods for hand-labour in the under-cutting of bituminous coal. The first machine turned out by this company was placed upon the market in the spring of 1880 (the first patent was issued to J. W. Harrison in December, 1877), so that this

FIG. 12.—AFTER THE BLAST

company has now a record of nineteen years in the manufacture of coal mining machinery, and has consistently stuck to the pick machine, although two patents on a different type of machine were taken out by Mr. George D. Whitcomb, one in 1871 and one in 1876. When first offered to coal operators, the machine was met with prejudices which were not easily overcome. Operators had to be convinced that it was practicable to under cut coal by machinery, so that the pioneers had in this respect, as well as in the mechanical defects, and the opposition of the miners' unions, a great deal of difficulty to overcome. In time, however, operators still employing hand labour learned that some of their competitors were effecting a satisfactory saving in the cost of mining by the use of machines, so that now we find the question asked by operators is, not whether the use of machines is a demonstrated success, but what type of machine is going to perform the best work with least cost, considering all the conditions of the mine, the original cost of installation, and the expense of maintenance and operation.

Since 1880 the Whitcomb Company has turned out about 1700 pick machines, and while some of the very first ones made have been discarded, there are still in use many of the machines made in 1880 and 1881, and they seem to be giving entire satisfaction. All parts of each pattern are made interchangeable to facilitate and cheapen repairs.

The working tool of a machine of this class is in principle a projectile, and the energy of the blow is measured by its weight and velocity; therefore, after the piston, with the pick attached, has acquired the required velocity, it is not only economical of power to have the valve cut off the inlet of the air to the cylinder prior to half-stroke, but it greatly reduces the recoil of the machine upon the operator, reducing his fatigue and enabling him to keep the machine in better working position.

The machine is mounted on wheels, the height of these varying according to conditions found in the different mines. The general sizes vary from 16 to 18 inches in diameter. This feature enables the operator to work under or

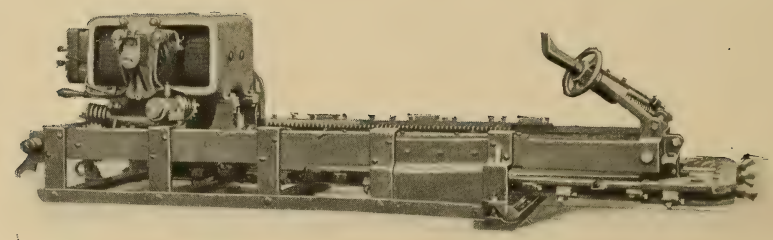


FIG. 13.—ANOTHER VIEW OF A JEFFREY ELECTRIC CHAIN MACHINE

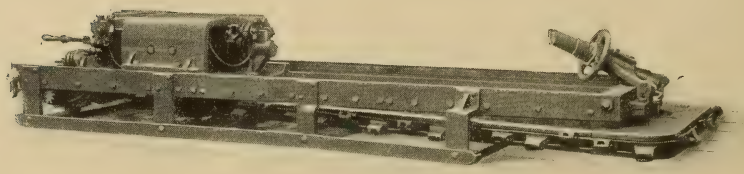


FIG. 14.—A JEFFREY ELECTRIC CHAIN MACHINE FOR THIN VEINS

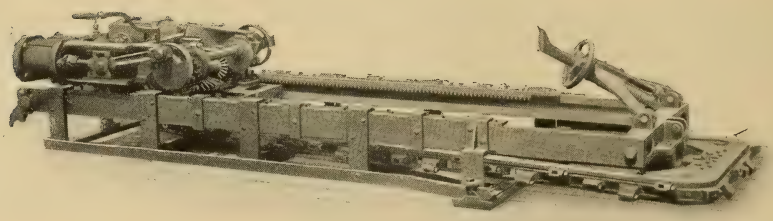


FIG. 15.—A JEFFREY CHAIN MACHINE DRIVEN BY COMPRESSED AIR MOTORS

FIG. 16.—ANOTHER VIEW OF THE STANDARD MORGAN-GARDNER ELECTRIC CHAIN MACHINE

over nodules or segregations of pyrites encountered in mining, and dislodge them. Although it is not claimed that the machine will cut as fast or mine as much per day in hard beds, where pyritic segregations exist in large quantities, yet it is doing good, practical work in very hard material containing large amounts of these impurities. The manufacturers claim that it will mine in any strata where mechanical methods can be used, and that it will mine in strata where it is imposible to use the chain or rotary-bar machines. The coal, the operator allows the machine to run forward down the platform. A helper shovels away accumulated cuttings, using a special long-handled, flat shovel. Only two men are required to operate the machine, one skilled man as runner and an ord nary labourer as helper. Two platforms are used for convenience, so that when the machine has completed the cut on one, it can be moved to the next without stopping, the helper shifting the platforms as they are vacated. If desired, a cut to the full depth can be made to the full width

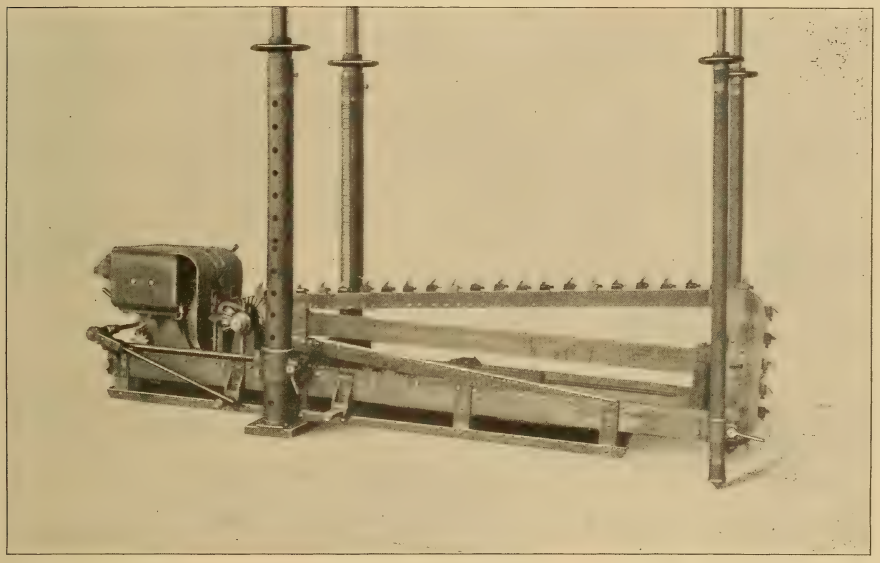


FIG. 17.—A JEFFREY STANDARD SHEARING MACHINE READY TO CUT

speed can be varied at will, making the blow light and rapid or hard and slow, as occasion requires.

The only part that comes in contact with the coal is the pick, which is easily removed and replaced by a sharp one when it becomes dull, and which can be sharpened by any blacksmith with an ordinary forge. The machine is mounted on platforms, which are so inclined to the face of the coal that the recoil of the machine is neutralised by gravity; this also holds the machine to the coal. The pick strikes from 190 to 210 blows per minute, as the operator may desire, and as it works under the of a room without stopping the machine.

The manner in which the machine attacks the coal is very much like that of a hand miner. The cut can be made of any desired height or depth, as the occasion demands; it is generally from 8 to 10 inches in height in front and tapers to 2 inches in the rear, making an average of 6 inches in height. A depth can be made as desired up to 5½ or 6 feet. The cut, being V-shaped, leaves the coal in the best possible shape for blasting and loading, as, on being thrown down by a light charge of powder, it will roll over and out of its orig-

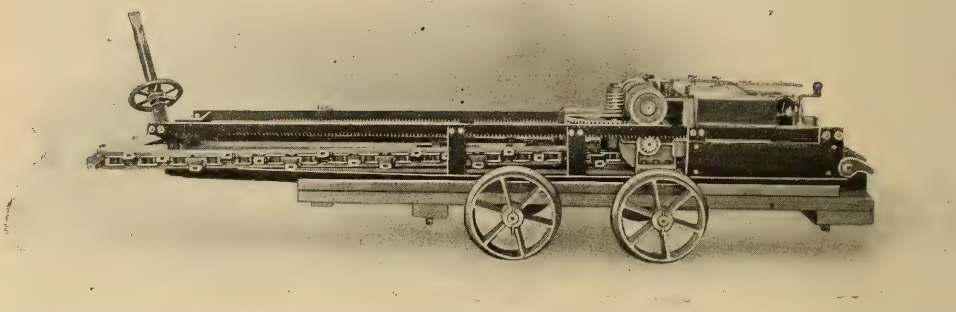


FIG. 18.—A LOW-VEIN ELECTRICALLY DRIVEN CHAIN MACHINE MOUNTED ON A PLAIN TRUCK, MADE BY THE MORGAN-GARDNER ELECTRIC CO.

inal position and can be free for attack by the loaders. This feature will be appreciated by all practical mining managers.

The machine made by the Ingersoll-Sergeant Drill Company, of New York, is the development of ten or fifteen years' experience. The first machine turned out by this company was, to all outward appearance, similar to the present one. The interior arrangement, however, is radically different. When the runner swings the machine sidewise, or if for any other reason the pick misses the coal, the first blow missed builds up a cushion pressure which instantaneously throttles down the air supply, so that, while the machine will keep up its reciprocating motion, it strikes lightly instead of with the full pressure. When the pick again comes in contact with the coal the full pressure of air is immediately turned on and the machine resumes work at full force.

These machines have been used in mines where the coal dipped at an angle of 23°, and, although the progress was slow and difficult, the result could be called successful when the labour conditions were considered. Ordinarily, however, it does not pay to use this or any other pick machine when the pitch is more than 12° or 14°, and even then accompanying conditions should be favourable. The manufacturers say that they have never encountered a bituminous coal either so hard or so soft

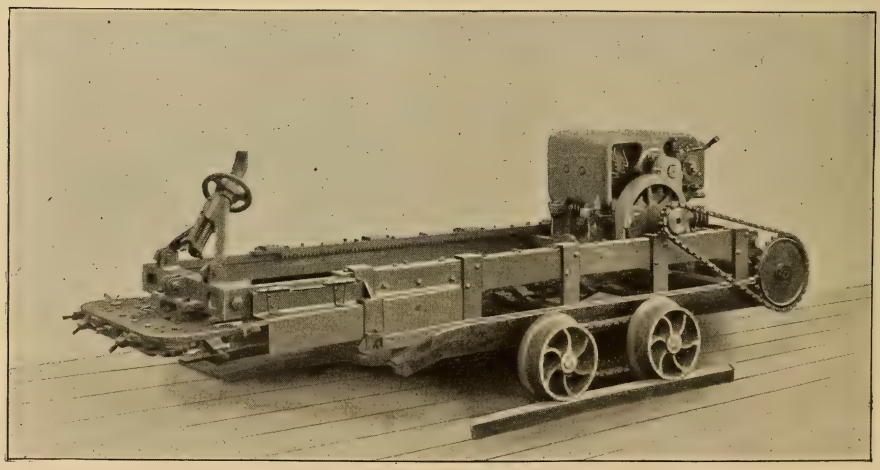


FIG. 19.—A JEFFREY ELECTRIC CHAIN MACHINE MOUNTED ON A SELF-PROPELLING TRUCK

that it could not be mined to advantage with their machine, as compared with hand-labour, but frankly admit that under extreme conditions of very soft coal and very cheap labour, machines might not prove profitable.

The Sullivan pick machine, made by the Sullivan Machinery Company, of Chicago, is shown in Fig. 8. Although this machine is capable of being converted into a shearing machine by simply placing it on higher wheels, the makers have not been content to let it rest at that, but have evolved a shearing machine in which the principle of the pick-cutter is retained. It is, in fact, the pick machine with an extension arm and mounted on a special truck, as shown in Fig. 6. The truck or carriage is built of sufficient strength and weight to take up all the shock of blow and recoil, and neither of these is felt by the runner. The truck is mounted on four wheels, which are kept on the tracks. The forward ends of the tracks are laid up close to the face of the coal and the rear ends are held in place by a jack set to the roof. The machine is held to its work and is fed forward by means of a chain passing over a sprocket wheel and connected to both ends of the rail. The machine is never taken from the mine tracks, and is moved from place to place as an ordinary mine car. The machine makes a cut 6 inches wide, 7 to 8 feet deep, and from the roof to the floor. An eight months' run, operating in a 7½-foot vein, showed an average of 30 feet per shift of ten hours. Two men are required to operate the shearer, one to run it and the other to keep the cut clean. They do all the moving and setting up, and after once becoming accustomed to the work, do it easily and rapidly. The fact that the runner does not receive any of the shock gives the machine a decided advantage over the under-cutting machine mounted on high wheels.

THE CHAIN-BREAST MACHINE

The first use of a chain cutting machine which has succeeded the rotary bar and now contends for supremacy with the pick machine is of quite recent date. The inventor of the first successful chain machine was Francis M. Lechner, the inventor also of the rotary-bar machine, although letters patent had previously been granted to Samuel C. Lechner and Van Amberg Lechner on inventions involving the chain principle. F. M. Lechner's patent, obtained in July, 1890, was on a single endless chain, operating continuously in one direction; the former patents, issued in October, 1883, and April,

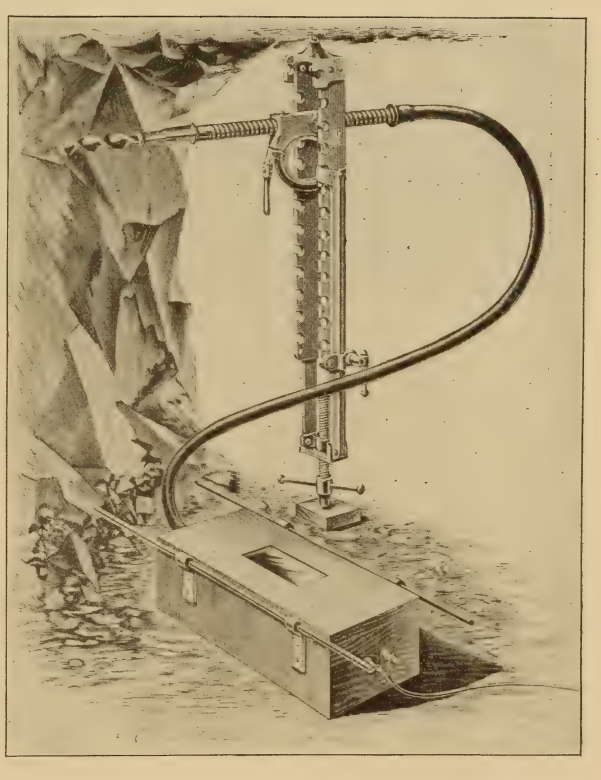


FIG. 20.—AN ELECTRIC COAL DRILL MADE BY THE HARDY PATENT PICK CO., LTD., SHEFFIELD, ENGLAND

1886, were on inventions which involved the use of two chains operated in opposite directions. F. M. Lechner's invention proved practicable; the others did not. The F. M. Lechner patents were assigned to the Jeffrey Manufacturing Company, of Columbus, Ohio, and the present Jeffrey chain machine is the development of these patents.

As stated, Lechner obtained his patent in 1890, but the chain type of machine was not put upon the market until 1894, in which year three different companies entered the field. These were the Jeffrey Manufacturing Company, the Morgan Gardner Electric Company, and the Link-Belt Machinery Company. The coal mining machine business of the last mentioned company has since been transferred to the Goodman Manufacturing Company. A few chain machines were also made by the General Electric Company, of Schenectady, N. Y. The arrangement of the cutting device, the endless chain, was practically identical in all four machines, the differences being in details of construction of the framework, motors, and gearing which gave to each machine claims of superiority over its competitors. As a natural result there has been a somewhat lively and interesting litigation over alleged infringements, and some points of the controversy are still unsettled.

In the use of the chain machine the coal is attacked at right angles to the direction followed by the rotary bar. The chain, with its cutting-bits, is driven, either by compressed air or electricity, as the case may be, at a speed of from 250 to 275 feet per minute; and the movable frame, carrying the chain and the motor, is fed forward at a speed determined by the resistance offered by the coal. The rear end of the machine is securely held in place by means of a jack, set to the roof, while the forward end is secured by a jack set at an angle of about 45° into the face of the coal. The forward jack is placed at this angle in order to overcome the tendency of the machine to be forced sideways as the chain cuts the coal. Figs. 9 and 10 illustrate the operation of cutting coal with chain machines. The original photographs were taken under actual working conditions and give accurate details of the machines in position for making the cut. Fig. 11 shows the operation of drilling for the blast, and Fig. 12 shows the coal blown down.

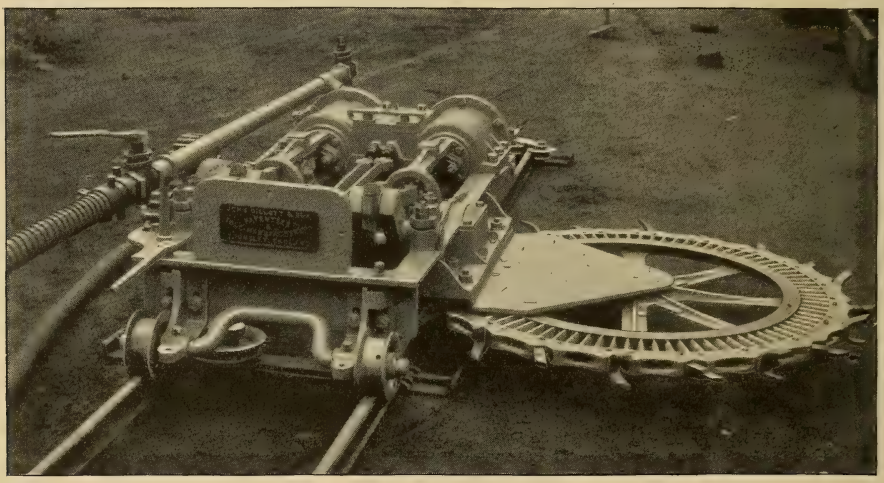


FIG. 21.—A LONGWALL COAL CUTTER DRIVEN BY COMPRESSED AIR. MADE BY MESSRS. JOHN GILLOTT & SON, BARNSLEY, ENGLAND

One of the most notable, and, so far, practically the final step in the development of a successful mining machine

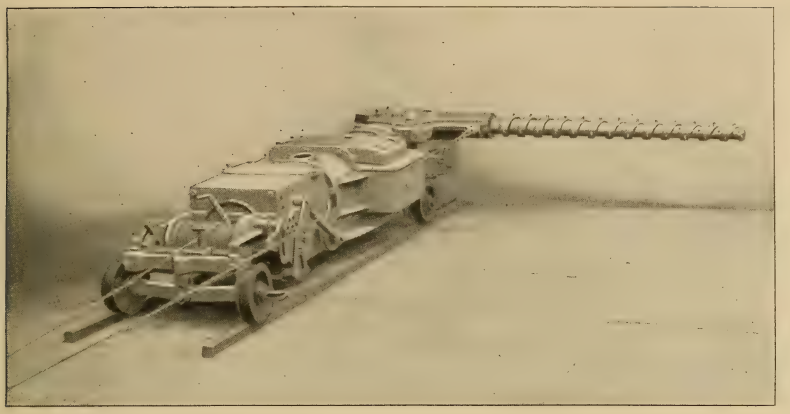


FIG. 22.—AN ELECTRIC BAR COAL CUTTER. A LONGWALL TYPE. MADE BY MESSRS. MAVOR & COULSON, LTD., GLASGOW

was made when the chain machines were brought out. The speed with which one of these machines will do its work seems almost incredible. An average of five minutes, after the machine is in position, required to make a cut 6 feet deep, 44 inches wide and 4½ or 5 inches high, and to withdraw the cutting frame, is the ordinary measure of the effectiveness of this type. A record of 1700 square feet of cutting in nine and a half hours is claimed for one of these machines. This would mean about seven and a half minutes to each cut 6 feet deep and 44 inches wide, including the moving and setting of the machine. This record must have been in a competitive test, for the writer's observation has been that more time is taken in moving and setting the machine than in making the cut. All of these machines are supplied with an automatic cut-off which stops the machine when it has reached the end of its travel, either forward or backward. The return travel is made in about one-fourth the time required to make the cut.

Mention has been made of some of the advantages possessed by the pick machine. The chain machine bases its claims upon the rapidity with which it does its work, the very small amount of slack coal made in the cutting, and the fact that the runner is not subjected to the racking action of the pick machine.

LONGWALL MACHINES

Comparatively few coal mines in the United States are operated strictly upon

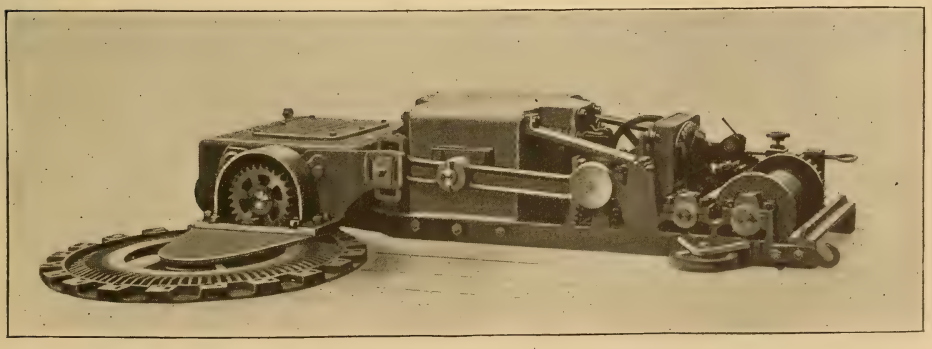


FIG. 23.—A JEFFREY LONGWALL MACHINE

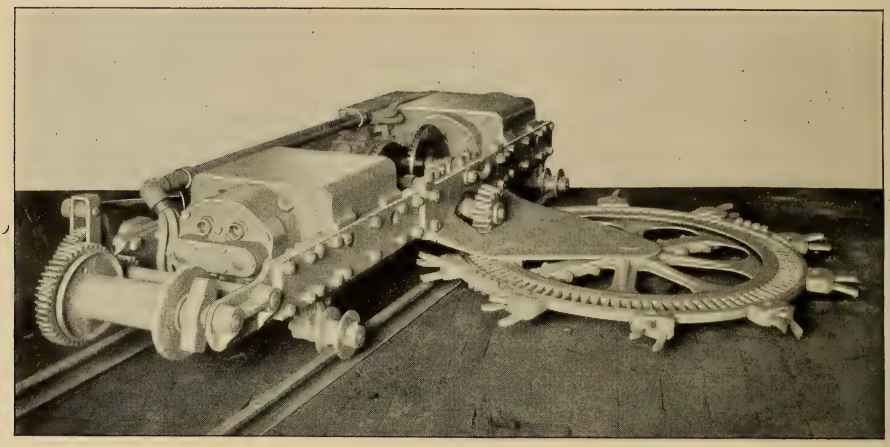


FIG. 24.—AN ELECTRIC LONGWALL MACHINE OF THE DIAMOND COAL CUTTER CO., NORMANTON, ENG.

the longwall system. Although this method is usual in Great Britain and on the Continent, its employment in America has been confined almost entirely to the thin seams of the States in the Middle West.

In the longwall system of mining the coal is, as the name implies, extracted from a long face which is gradually moved forward. If the shaft is sunk in about the centre of a coal bed, the actual mining is begun at a distance from the shaft bottom, enough coal being left around the shaft to insure its safety, and the work is drawn forward in gradually enlarging, irregular circles. The very nature of longwall work requires a jagged or circular face, quite different from the straight, even face encountered in room-and-pillar mining. The irregular lines made in the faces of longwall mines were responsible for the many failures attending the early attempts to use mechanical undercutters in such mines.

The earlier types of longwall machines appear to have been built in Great Britain, but their introduction was notable chiefly for their failure to accomplish the work for which they were intended. They were heavy, cumbersome, and uncertain in their action, and required a practically straight track upon which to run They were not self propelling, and had to be moved forward by reeling up a rope or chain which was anchored ahead.

Few accurate data as to the use of machines in Great Britain and on the Continent are obtainable. Dr. C. Le Nevi Foster, one of His Majesty's inspectors of mines, in his report to the home office for 1899, lays particular stress upon the rapid strides made by the United States in the mechanical mining of coal, as compared with other countries, and attributes America's present supremacy as a coal producer and in the manufacturing branches of industry to the economies effected by machine-mining. The report does not give the number of machines in use in Great Britain, nor do the statistical reports of other countries furnish any information of this kind. Dr. Foster states, however, that only 3,500,000 tons, or 1½ per cent., of Great Britain's coal product in 1899 were mechanically won, whereas 23 per cent. of the bituminous coal produced in the United States (nearly 44,000,000 tons) in the same year were machine-mined. The returns to the United States Geological Survey for 1900 show that the machine-mined product in that year was over 52,000,000 short tons, or 25¼ per cent. of the total bituminous product.

Among the machines of British manufacture which have been used in Great Britain to some extent were the Gillott & Copley and Rigg & Meiklejohn, both of which undercut the coal by teeth set in the periphery of a wheel or disc; the

Baird, which operated an endless chain carried on an arm which extended from the side of the machine, not unlike in action to the chain breast machines; and the Goolden, whose cutting tool consisted of a rotating bar with teeth set in its sides.

In the United States the Jeffrey Manufacturing Company, of Columbus, Ohio, developed a longwall machine that met the exactions placed upon it. In 1891 E. A. Sperry, of Chicago, Ill., obtained a patent on a longwall machine which was found to be well adapted to certain local conditions in the thin seams of Kansas and Missouri, and these machines are still being used in some of the mines of that section, but their usefulness was so restricted that the machine is no longer on the market.

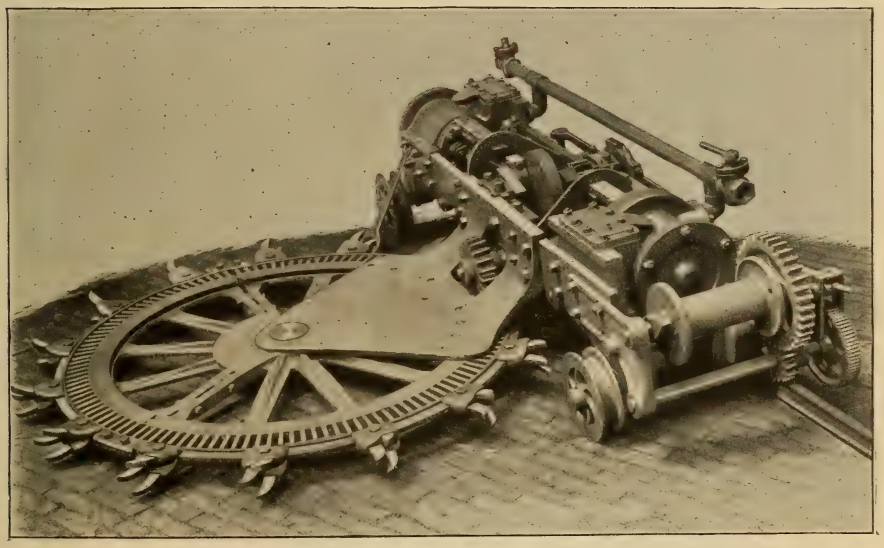


FIG. 25.—A COMPRESSED AIR LONGWALL MACHINE, MADE BY THE DIAMOND COMPANY

The longwall machinery built by the Jeffrey Manufacturing Company is shown in Fig. 23. Most of it is built for export trade. The machine consists of two distinct parts, the motor and feeding gear on its frame, and the cutter wheel. The frame is rectangular, and a drum located at its forward end mechanically winds the rope which draws the machine along the face of the coal. The motor is located in the middle of the frame, and the cutting wheel projects from the rear end a distance sufficient to cut the coal to the desired depth. This disc is provided with a tilting device with the use of which it is possible, while the machine is at work, to move the cutter wheel so that it will follow any unevenness in the floor or cut over or under any hard foreign substance, such as pyrite, which is frequently encountered. A device is also provided for altering the speed of travel of the machine along the rail without changing the speed of the cutter wheel. This machine operates on a single rail, which is held in place by suitable jacks. The operator, with his helper, can easily take up a section of the rail over which the machine has passed and relay it in front without stopping the machine.

It has not been possible to secure any reliable data as to the results effected by the use of these machines. The reason assigned for this by the manufacturers is that companies adopting them prefer not to divulge what benefits have been derived from their use. Tests have shown that one of the machines will cut from 500 to 800 linear feet in one day, the cut being 3, 4, or 5 feet deep, according to the diameter of the

cutter wheel. The speed is, of course, dependent, to great extent, upon local conditions, such as the nature of the floor, the hardness of the coal, and the efficiency of the men.

It must be remembered that in longwall mining the great weight thrown upon the face of the coal makes it necessary for the timbering to be brought up to within a few feet of the coal, so that it would not be possible to leave enough space to operate the chain breast or punching machines in this system of mining. It is necessary to have a machine that will work in a narrow space, say 5 feet or less, whereas the chain breast machines require 10 or 12 feet in which to operate, and 6 or 8 feet are required for the proper running of the punching machines, although with the latter it is possible to work with the timbering brought up close to the face, the machine working around the timbering. It has not been found satisfactory, however, in longwall practice.

An interesting and successful type of longwall machine was patented in 1896 by three brothers of the name of Lee, living in Centerville, Ia. It was the development of an attempt to meet the needs of a comparatively small mine near that town. The inventors are the owners of the mine, and the machine has not been manufactured for sale. Its success in meeting the requirements of the mine, however, makes it worthy of notice in this paper. Briefly stated, the principal features of the perfected machinery are the cutting tool and the self-propelling device. The former consists of a long arm or bar upon which the cutting teeth are set in a spiral. As the bar revolves and the coal is cut, the spiral acts as a screw conveyor to bring the fine coal out of the cut. The machine is made to run on two rails, which are made of ordinary angle iron riveted together. The outer rail is made with two pieces of the angle iron riveted close and forming an inverted T section, thus ⊥. The inner rail is made by using rivets upon which shoulders are cut, so that the angle bars are kept 1⅛ inches apart. The rivets are set at intervals of 1½ inches, the effect being that of a flat-bottomed rack-bar. This rail is braced against the coal and the roof. The outer rail is not braced. The machine propels itself along the face of the coal by means of a toothed wheel meshing with the rivets of the inner rail. This feature is unique and makes the machine different from any other of the longwall machines.

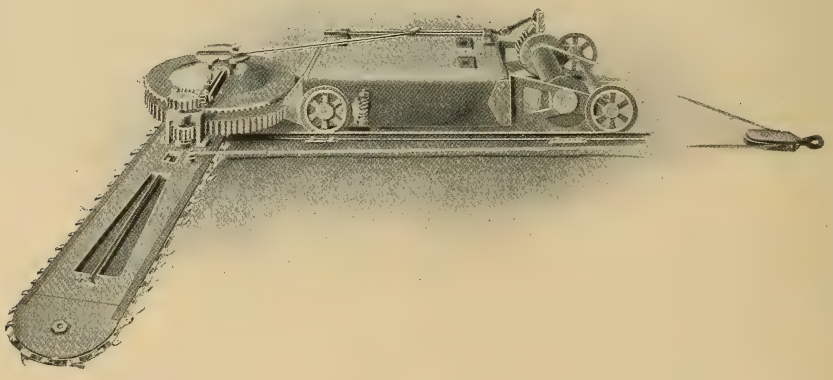


FIG. 26.—THE LATEST FORM OF AMERICAN LONGWALL MACHINE. MADE BY THE MORGAN-GARDNER ELECTRIC CO., CHICAGO

Two men operate the machine, which is driven by electricity, although compressed air may be used with equal efficiency. The two men can take up the rails back of the machine and reset them forward without stopping the ma-

chine. Two of each rail are all that are required.

The reports to the United States Geological Survey for 1900 show that there were forty-eight longwall machines in use in the coal mines of the United States in that year. The total number of machines of all kinds in use in 1900 was 39,071, and the total machine-mined product amounted to 52,790,523 short tons, which was equal to the entire output of anthracite and bituminous coal in the United States in 1875, and was larger than the total coal product of any other country of the world in 1900 except Great Britain and Germany.

The very newest type of longwall machine to be put upon the market is the invention of Mr. Ralph E. Noble, C. E., whose patent for which was assigned to the Morgan-Gardner Electric Company, of Chicago, manufacturers also of the chain breast machines previously described. This new machine is illustrated in Fig. 26, and it will be seen that it differs essentially from the two other types of machines. The cutting parts consist of an endless chain operating along a narrow frame or arm extending from the side of the machine, involving, to a certain extent, the principle of the chain breast machine. The arm or frame is so adjusted as to be operated at any angle up to a right angle. By the changing of the angle of the cutting frame the thrust on the track is diminished and the machine will follow any irregularities of the coal

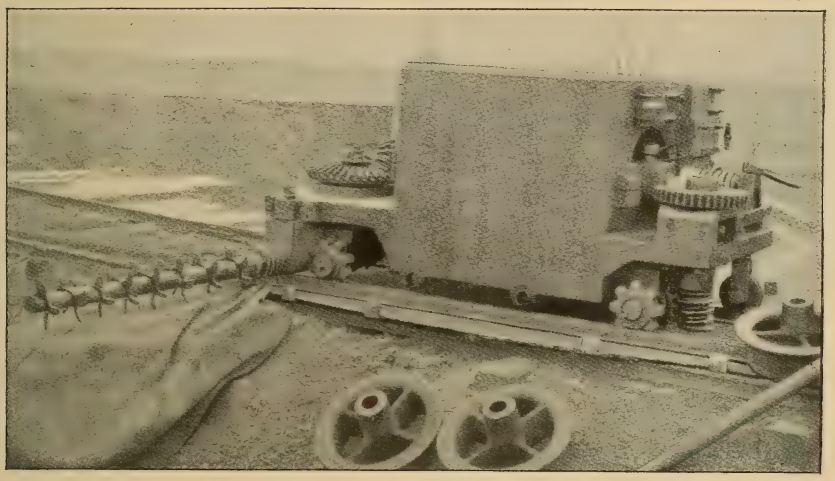


FIG. 27.—THE LEE LONG WALL MACHINE

ace. The machine is constructed in such manner that it may be operated with the cutting frame extended from over the right or left side of the machine, so that the cutting can be accomplished by the machine as it moves in both directions along the face of the coal. It has a wide range of cutting speed which is regulated by a simple device, and by the swing of the cutting frame can be made to undercut to any practical and desired depth. The cutting frame may be swung out behind the machine when going through narrow places, and when moving or changing the cutting bits. It may be operated by two men, as in the case of the ordinary chain machines.

The manufacturers claim for this machine that it may be used in the room-and-pillar system, as well as for longwall mining. Its weight is about 3000 pounds. Its height is only 18 inches, which enables it to be operated in very thin seams.

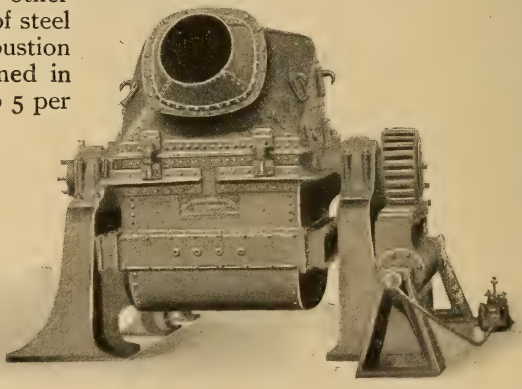
BESSEMERISING OF COPPER AND COPPER MATTES

By Dr. James Douglas

FOR centuries the metallurgy of copper remained almost at a standstill. The two systems of furnace treatment, namely, the English, in open reverberatory furnaces, and the German, in small shaft furnaces, underwent trifling modifications. Progress was retarded by an almost superstitious respect for tradition and the intense narrowness of the Welsh, who were alone believed to possess the secret of copper refining, about which an impenetrable mystery was, to their great profit, supposed to hang.

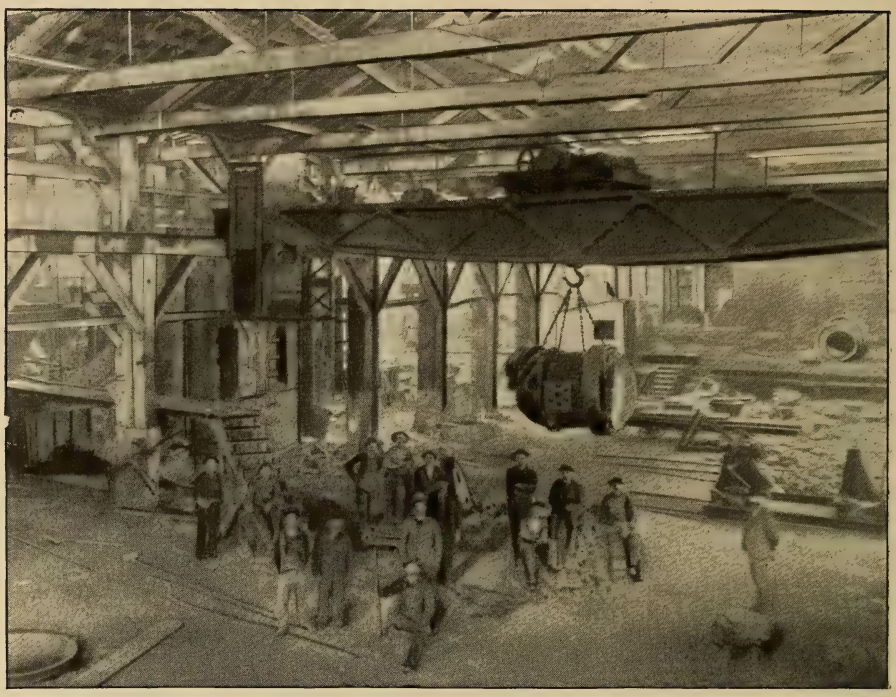
Bessemer's great invention not only transformed the steel trade, but it broke down the conservatism which oppressed every branch of metallurgy. If such a nice and difficult process as steel making could be simplified, and tons be made and handled with less exertion than pounds, men asked themselves whether a like revolution could not be effected in the treatment of other metals. The Bessemer process of steel making is based on the combustion principally of the carbon contained in pig iron, which varies from 2 to 5 per cent., till it is reduced to the percentage of carbon which should be contained in soft steel, say, one half of one per cent. Silicon and other ingredients of pig-iron, whose total percentage with the carbon does not exceed 8 per cent., also undergo combustion. This combustion is effected by driving air through the molten pig-iron. The heat generated by the rapid combustion of the carbon and silicon is so great that the mass of molten pig-iron in the converter remains fluid despite the small quantity of the material oxidised. But Bessemer was a mechanic as well as a theorist, and his success really depended on his ingenious adaptation of mechanical appliances to the chemical reactions on which the process depended. The chemical facts on which he based his reasoning had long been known, but not till he devised machinery for taking advantage economically of this knowledge and controlling the chemical forces which were known to exist, waiting only to be marshalled and led, was the pneumatic era of metallurgy inaugurated.

As soon as the Bessemer process, and the machinery for practicing it, were generally accepted, and their suitability for the rapid smelting of copper ores and the concentration of copper mattes to metallic copper was appreciated, experiments were made to apply them. The most thorough series of experiments was carried on by Mr. John Hol-



THE STALMANN CONVERTER. A SQUARE TYPE. MADE BY THE ALLIS-CHALMERS COMPANY, CHICAGO

POURING A CHARGE OF COPPER FROM A BESSEMER CONVERTER AT THE WORKS OF THE COPPER QUEEN MINING CO., BISBEE, ARIZONA, U. S. A.



A CONVERTER IN TRANSIT TO BE FILLED AT THE MATTE FURNACE AT THE WORKS OF THE MONTANA ORE PURCHASING COMPANY, BUTTE, MONT., U. S. A.

loway at steel works in Great Britain in 1878 and 1879, though long prior to that date attempts had been made in Russia and Germany to apply the pneumatic method to copper smelting.

Certain classes of copper ores like those of the Huelva district in Spain consist essentially of iron, sulphur, and copper, the copper constituting a very small proportion of the mass. These sulphur ores differ from most ores of copper in that they contain no earthy matter, as gangue, and, therefore, they approach in composition the mattes which are the first products of the smelting furnace; for whatever furnace be used, the object which the copper smelter has in view, when treating a sulphuretted ore, is first to separate the mineral portions from the earthy gangue. This mineral portion after its separation by fusion is known as "matte," whose constituents are always copper, iron, and sulphur in varying proportions. The earthy ingredients of the ore, smelted, enter the slag. Heavy sulphur ores differ, therefore, from matte, apart from the fact that one is a natural and the other an artificial product, in the greater percentage of copper which matte usually contains.

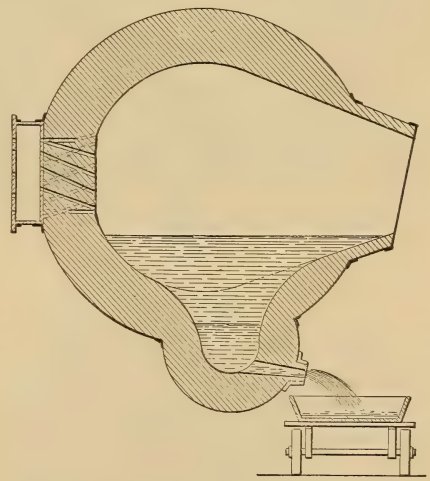
Holloway's experiments were made with ore, and his object was to use the heat generated by the oxidation of iron and sulphur in fused Rio Tinto ores to not only maintain the matte in a liquid state, and concentrate it in the hearth of a furnace; but, while concentrating it, to smelt the ore into matte in the shaft of the same furnace without fuel. He was, therefore, attempting the heroic task of effecting pyritic smelting and of Bessemerising in the same composite apparatus. His failure was sufficiently near a success to prove the possibility of thus smelting complex ores and extracting the matte in one operation without extraneous heat, and encouraged others to prosecute attempts to smelt without fuel in the proper furnace, and to concentrate the matte thus made in a separate converter by the in-

jection of air. The smelting and the concentrating are, in fact, analogous operations, both depending upon the oxidation of the same ingredients of the ore. But when applying a pneumatic method more success has been obtained in the latter operation than in the former. This success has resulted from slight mechanical changes in the converters used for steel making. The alliance between chemistry and mechanics in this case has again lent aid to both.

In the experiments on Bessemerising copper, the process of concentrating matte, by the elimination of its iron and sulphur constituents, proceeded without serious impediment until metallic copper commenced to form. This, being heavier than either the matte or the slag, sunk to the bottom of the converter, and there coming in contact with a current of air, froze and obstructed the tuyeres. Unlike molten pig-iron, which is not a metal, but an alloy of iron and several metals, all of which evolve great heat during oxidation, copper, when it commences to form under the influence of the blast, separates as a metal which oxidises so much more slowly than even iron that the heat given off by its own oxidation does not suffice to maintain it in a fluid state. When, therefore, the experiments were made in the ordinary steel converter, the metallic copper chilled, the tuyeres became occluded, and the operation stopped.

In the steel converter the tuyeres are vertical, and let into the bottom of the egg-shaped vessel in which the molten pig is blown up into steel. In the converter as applied to copper the tuyeres are elevated above the bottom. The copper, therefore, when formed, settles below the level of the tuyeres, and the tuyeres, being horizontally set, can be easily reached through valves in a wind box and punched clear of any copper, which clogs them. The idea of thus elevating the tuyeres was entirely due to M. Manhès, of the Aiguilles Works, in France; but the credit for working out practically the structural details of the modern copper converter must, in the main, be accorded to Mr. Franklin Farrel, of Ansonia, Conn., U. S. A. He was the first in the United States to appreciate the value of this momentous innovation, and to introduce it at his Parrot Works, in Butte, Mont. The converter originally designed by M. Manhès and adopted by Mr. Farrel was vertical, with tuyeres elevated about 10 inches above the lining and encircling the shell. Access to the tuyeres was given through a wind box, so that, if necessary, they could be punched when obstructed by chilled copper towards the close of the operation.

Among the many designs for steel converters most have been built with long diameter vertical, but some have been made of barrel shape, revolving on their long diameter. Vertical bottom tuyeres are in almost universal use in steel works, but elevated tuyeres were among the earlier suggestions even for steel. So for copper, a variety of shapes and sizes for the converting ves-

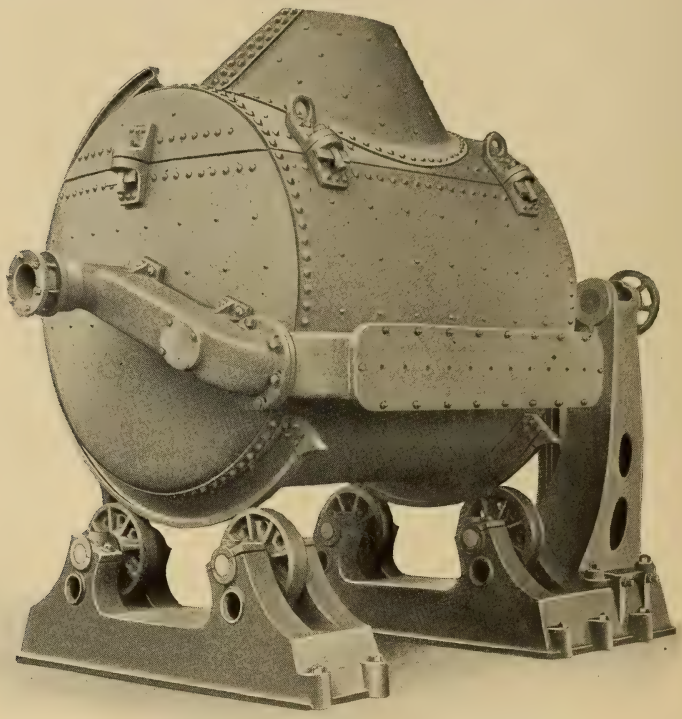


VERTICAL SECTION OF A DAVID CONVERTER

sels have been adopted, and even bottom tuyeres have been reverted to in a converter designed by M. P. David, of the very works at Aiguilles where M. Manhès first applied on a large scale his classical experiments. M. David's tuyeres are, however, arranged in a circle, and ascend through the bottom lining at an acute angle from the vertical.

This position enables them to be reached and punched with more ease than if they were vertical, and, it is claimed, gives a rotary motion to the contents of the converter.

A radical difference in the composition of the material treated in the copper converter, as compared with that in the steel converter, involves a modification of treatment and a provision in the structural details to meet these conditions. In treating pig-iron only about 8 per cent. of the whole has to be eliminated in order to convert the iron into steel, and of this nearly all escapes as gas. In extracting the copper from matte of, say, 45 to 55 per cent., all the foreign material has to be disposed of, about 25 per cent. of which is sulphur driven off as sulphurous acid gas, and 25 per cent. iron. The iron, after being oxidised by the blast, combines with silica, and is poured out of the converter as slag of no value. The proportion of iron to silica and the other earthy ingredients in converter slag generally approximates 50 per cent. The bulk of slag, which has to be maintained at a high heat, is, therefore, more than that of the iron itself, and thus much of the heat generated is consumed in producing slag and in maintaining this large volume of inert matter in a state of fluidity, a cardinal difference between the conversion of pig-iron and copper matte.



THE BISBEE CONVERTER, MADE BY THE ALLIS-CHALMERS COMPANY

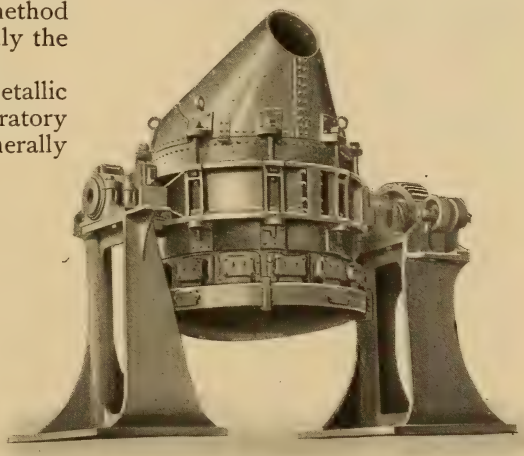
The silica is an extraneous substance and has to be supplied to the charge. Various methods have been proposed for doing this; but the only one, universally adopted, is to line the iron shell of the converter with a very silicious paste and allow the iron of the charge to feed on it. In the steel converter a refractory rock known as ganister, which resists the high heat, is employed as lining; but it is only slowly acted upon,

and need not be often replaced. As the silica lining of a copper converter, however, has to supply the acid necessary to satisfy the iron, which is a base and which constitutes generally 25 per cent. of the charge, it has to be renewed much more frequently than the ganister of a steel converter. If the matte be low in copper and high in iron, the lining is eaten away faster than if it be high in copper and low in iron. When concentrating a matte of about 50 to 55 per cent. of copper, a lining is so corroded after five or six charges that the converter must be cooled and the lining built up to its original maximum thickness, which is, usually, about 18 inches.

The copper converter shell must, therefore, be designed with a top which can be readily removed and replaced so as to facilitate the frequent relining of the body. As the charge does not reach the cover of a converter, the wear and tear through chemical action and mechanical attrition on it is less, and, therefore, the lining on that part of the apparatus requires less frequent renewal. The silicious lining usually consists of quartz, or quartzite, ground up with sufficient clay to give the mass plasticity. It is pounded in by hand, or preferably by machinery. With the exception of these modifications in practice, and necessarily in the construction of the converter itself, the pneumatic method as applied to pig-iron is essentially the same as when applied to copper.

The matte to be blown up to metallic copper may be made in a reverberatory furnace or in the cupola. It is generally conveyed to the converter, while still molten, in a ladle operated by an electric crane. The converter is partially inverted to receive the charge, and the blast is turned on before the converter is restored to the vertical position. In the large vertical converters the depth of the charge is such as to require a blast of fifteen pounds to the square inch; but in the barrel-shaped converters the depth is less, and, therefore, the pressure of blast may be proportionately reduced. In this type of converter also, as copper separates, the converter is tilted on its trunnions, so that the blast may impinge only on the unreduced matte, thus further economising the blast. Copper may be made under as low a blast as three pounds to the square inch, but seven or eight pounds pressure are usually maintained.

A large volume of air, no matter what the pressure of the blast, is necessary in order to secure rapid combustion and maintain a high temperature. Four thousand cubic feet of air a minute should be blown through the tuyeres of a converter which will oxidise forty tons of 50 per cent. matte a day. When the blast is first turned on, showers of sparks and a green flame issue from the mouth of the converter, slag rapidly forms, and is thrown sometimes in sheets from the vessel. During this stage the iron in the matte is oxidised and combines with the silica and clay of the lining to form slag. Some sulphur escapes as sulphurous acid. But an examination of the contents of the converter, after about twenty minutes of blowing, shows that virtually all the iron has been eliminated, that about one-third of the sulphur has disappeared as gas, and that the copper contents of the charge have



ANOTHER TYPE,—THE PARROT CONVERTER, ALSO MADE BY THE ALLIS-CHALMERS COMPANY

SKIMMING SLAG FROM A COPPER CONVERTER

been raised to 78 or 79 per cent. It has become what smelters call "white metal," and corresponds approximately in composition to copper glance, which is an ore that has been produced naturally by slow oxidation from copper pyrites.

This slag-making stage completed, the converter is tilted, the slag is poured off, the converter restored to the vertical position, and the blow resumed. The colour of the flame turns from blue to orange. Metallic copper is now forming, and as the wind-gauge indicates that the tuyeres are being stopped up by chilled copper, punching must be steadily resorted to.

The completion of the operation is indicated to an experienced workman by the colour of the flame, by the peculiar noise made by the blast when forced through the bath of metallic copper, and by the particles of solid material ejected. So expert does a converter foreman become that, without even taking a sample, the copper contents of the charge, when poured, will almost invariably run from 99 to 99.25 per cent. A small quantity of infusible, granulated slag remains in the converter, which latter is now carefully examined. If the lining be considered still sufficiently intact to stand another charge, any weak points are merely patched, through the mouth of the vessel, with the plastic mixture of sand and clay. When the lining has become too thin the converter is hoisted out of its cradle and carried by the electric crane to the relining department.

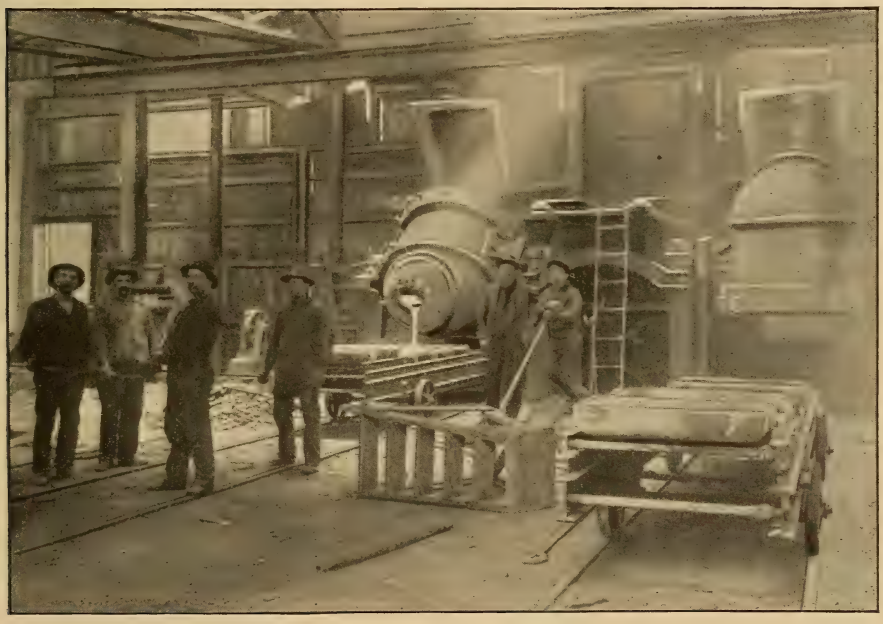
The process is applicable to matte of any grade, the limit of economical copper percentage being determined by the percentage of iron present, and, therefore, by the consumption and cost of replacement of lining. When suitable lining is available which carries value, whether of copper, gold or silver, there is no more economical method of extracting these metals than using the matrix of their ores to supply silica to the iron of the matte. If, however, the material for lining be barren and costly, it may be more profitable to concentrate the matte to a high percentage in the furnace, rather than in the converter.

But matte of over 65 per cent., unless poured very hot and into a very hot converter, responds slowly to the blast, owing to its small percentage of sulphur and iron. No universal rule can, therefore, be laid down as to the minimum quantity of copper which there should be in the matte. If precious metals be present, matte carrying much lead, zinc, antimony, arsenic, and any element which forms metallic compounds with silver, or is liable to carry off the precious metals in fumes, cannot be treated in the converter.

In practice, auriferous or argentiferous matte with 5 per cent. or over of either lead or zinc, or both, is precluded. This limit is fixed as safe at the establishment of Messrs. Guggenheim, at Aguas Calientes, in Mexico, where copper is used as an absorbent of gold and silver in the cupola, and where Pachuca ores, rich in silver, are used as lining. Arsenic and antimony are oxidised much more thoroughly in the converter than in either the reverberatory furnace or the cupola, and, therefore, a purer copper, better fitted either for market or for electrolytic anodes, is produced. If the converter slags are all returned to the furnace and the converter dust, which is considerable in quantity, is carefully caught, the loss of copper is very inconsiderable, for in treating pure matte the flame is very slightly tinted by copper. The loss of silver is found to be in no case 4 per cent. in excess of the loss of copper. The losses may be slightly in excess of those incurred in some of the older and more intricate processes, but the saving in cost and in time more than compensates for them.

The cost is included under the three items of power to operate the blowing-engine; labour; and lining material. The first, when water power is available, is slight; without such power and when fuel is expensive it is the heaviest of the three. The labour item depends on the arrangement of the works and the mechanical appliances for replacing lining and handling the converters, the slag, and the copper. The lining, as already explained, may be a source of profit instead of expense.

Even when the conditions are not the most favourable, the cost of converting



POURING A CHARGE AT THE WORKS OF THE MONTANA ORE PURCHASING COMPANY, BUTTE, MONTANA, U. S. A.

does not exceed eight-tenths of a cent per pound of copper produced, and under favourable conditions it is very much less. The speed of the operation and saving of labour, as compared with older methods, is simply marvellous. If the Welsh method be followed, the first matte, such as can be treated in a converter, undergoes two fusions, which proceed slowly so as to effect a preliminary partial roasting in bringing the metal to the condition attained at the commencement of the second blow. The white metal is then passed to the blister furnace, where it is exposed for about thirty hours to a gradually increasing heat before it is concentrated to as high a percentage as good converter bars. Days are occupied and about seven tons of coal are consumed to the original ton of matte, and the most laborious hand labour is expended.

If the older cupola methods be pursued, the matte is roasted and reroasted in stalls, an operation occupying at least six weeks; then it is fused in a cupola, whose product is metallic copper and white metal, which must be roasted before it can be reduced.

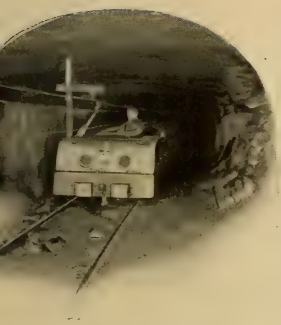
By the Bessemer process the same result is obtained in minutes instead of hours, by machinery instead of hand power, and in a space which is a mere fraction of what would have to be covered by furnaces and roasting stalls for any other method.

At the Copper Queen Smelting Works, in Arizona, which turn out between three and four million pounds of copper bars per month, the plant, including four furnaces and four converters, the ore bins, feed floors, relining stage, and bullion yard, covers a space of not more than 150 feet by 250 feet.

THE ELECTRIC LOCOMOTIVE FOR MINE HAULAGE

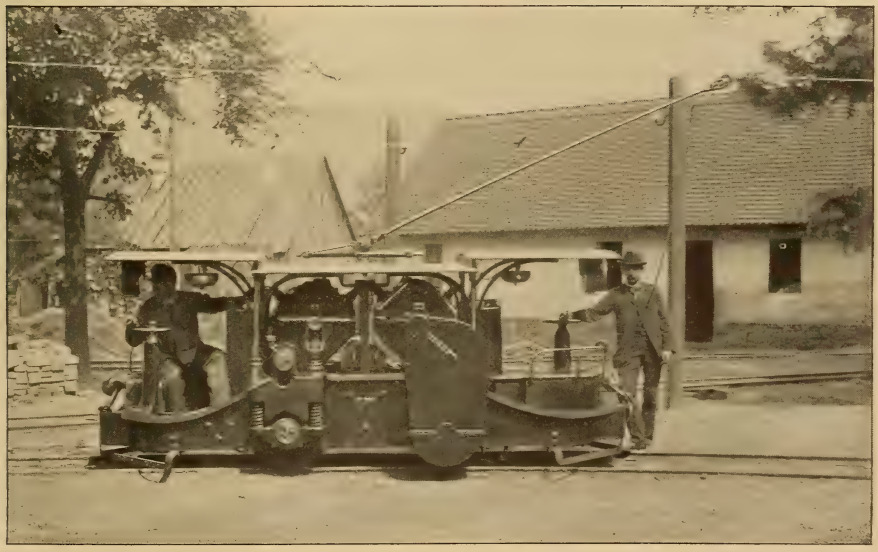
PRESENT PRACTICE AND ECONOMIES

By George Gibbs

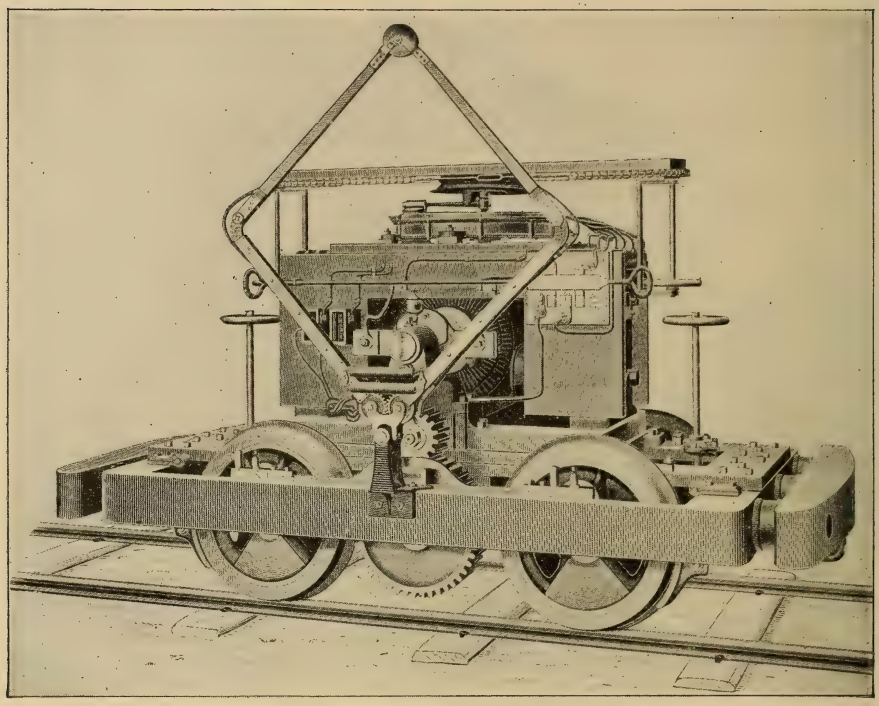


WHILE electric power for haulage purposes in mines was at first used experimentally, and with doubts as to its practicability on account of the novelty and somewhat refined character of the apparatus, it quickly demonstrated many practical advantages over all other existing haulage methods, so that during the past five years the electric locomotive has developed from the stage of an experiment to that of the preferred method of mechanical haulage for mining work. Accurate statistics are not obtainable for European mines, but it is estimated that 600 electric mine locomotives are now in operation in America, and this number is increasing at the rate of at least 100 locomotives per year.

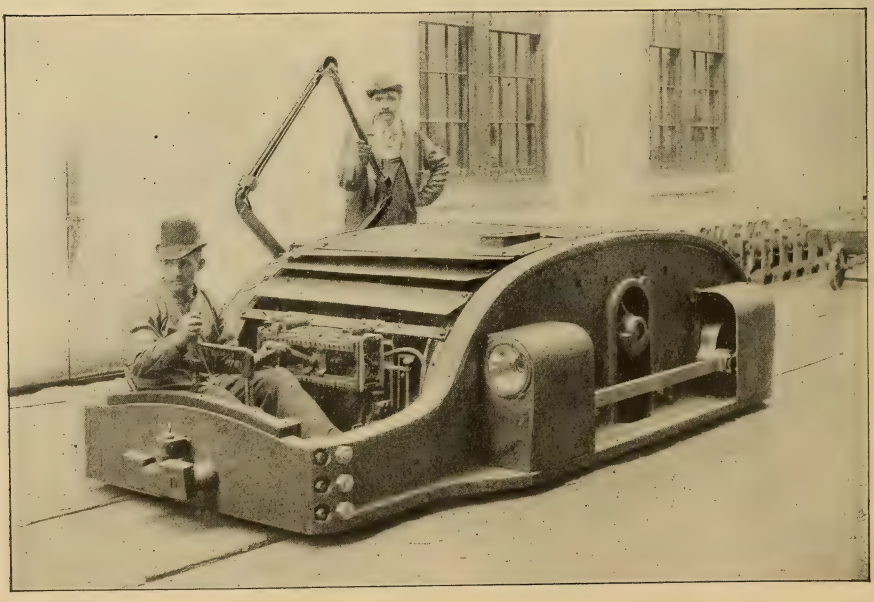
The development of electric haulage is best exemplified by modern American coal mining practice, especially in the mining of bituminous coal. It is in this field that the advantages of electricity are most apparent. Exended areas of thin and nearly horizontal seams, lying generally near the surface, access being gained by drifts in the hillside, enabling a single haulage system to be employed from the drift headings to the tipple, form conditions well suited for the economical operation of haulage by electric power. As illustrating the field to be covered in this class of work,



A TWO-MOTOR LOCOMOTIVE BUILT BY THE BRITISH SCHUCKERT ELECTRIC CO., LTD., LONDON



AN EARLY AMERICAN ELECTRIC COLLIERY LOCOMOTIVE. INSTALLED AT THE ERIE COLLIERY, NEAR SCRANTON, PA., IN 1889, AND STILL AT WORK

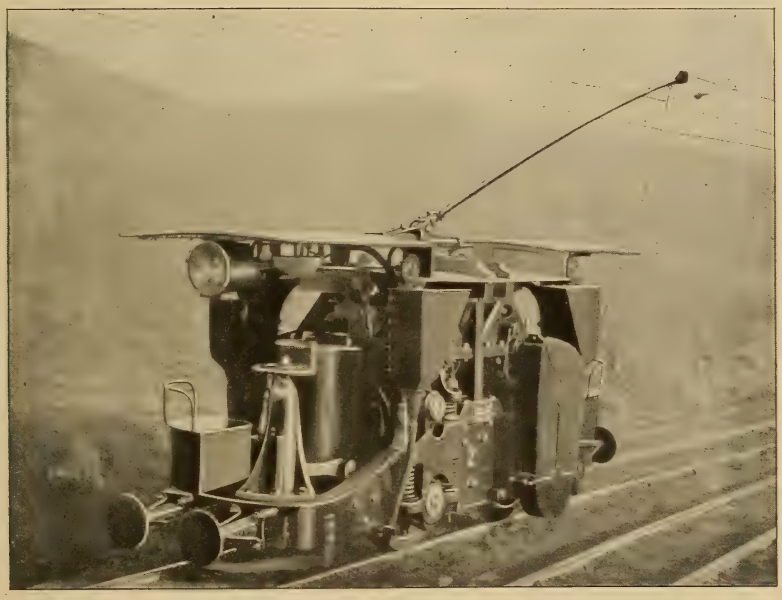


THE THOMSON-HOUSTON "TERRAPIN BACK" ELECTRIC MINE LOCOMOTIVE, USED AT FOREST CITY, PA., IN 1891. THE THIRD IN AMERICA

it may be mentioned that there are at least 20,000 miles of mine tracks existing in American coal fields.

Brief mention of the various functions to be performed by mine haulage plants and the existing state of the art will, perhaps, assist the reader to a better understanding of this field of usefulness for electricity in its relation to haulage and auxiliary purposes in mine operation. Mine haulage may be thus classified:—

a. Shaft hoists, for relatively deep mines.



A LOCOMOTIVE BUILT BY MESSRS. GANZ & CO., BUDA-PESTH

b. Inclined plane hoists, for main entry or for cross-heading purposes, where grades are heavy.

c. Main entry haulage, where the grades are light.

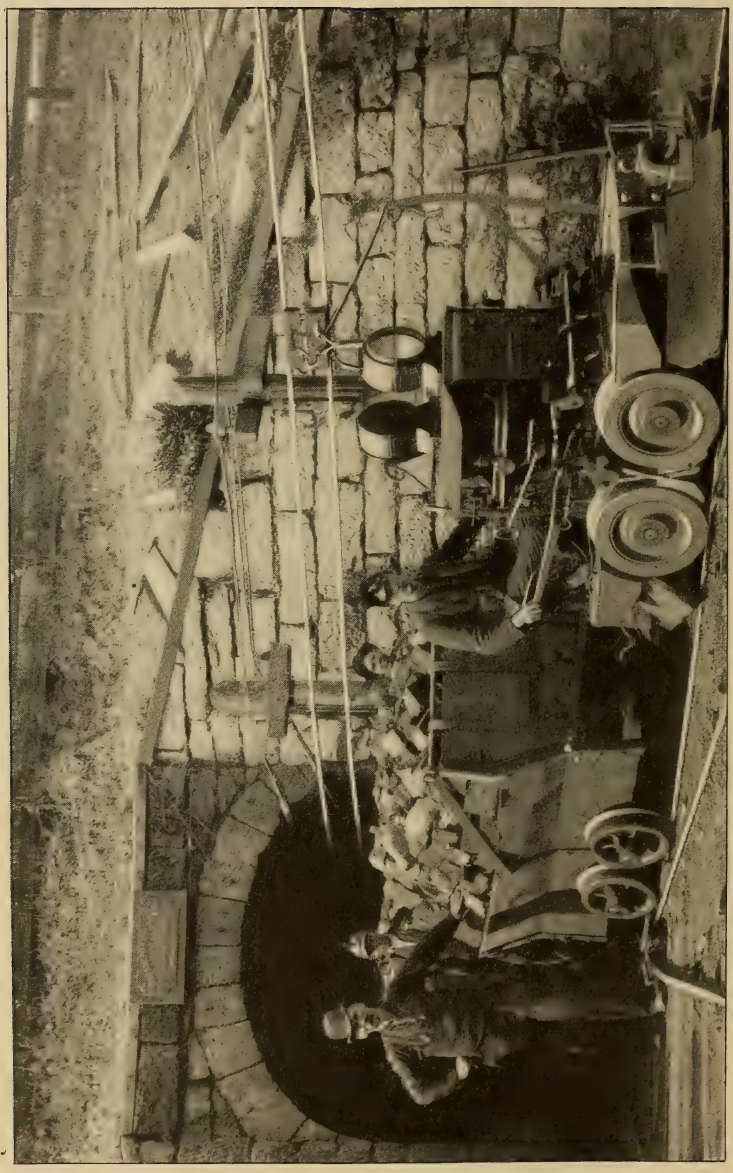
d. "Room" haulage.

e. Surface haulage to the tipple.

The systems in use for accomplishing the above purposes are, rope haulage ; animal power—either man, horse, or mule, and locomotive haulage.

a. For deep shaft hoists, which consist essentially of a cage, ropes, and winding drum, electric motors have, as yet, been employed only to a limited extent. Their advantage over steam-engines depends greatly upon local conditions, increasing with the number of adjacent shafts to be operated and with the cost of the fuel used. This follows from the possibility of using large, high-economy engines in a centralised plant, or by the utilisation of water power. Many examples of electric shaft hoists are already found in Continental Europe, and with the recent introduction of polyphase, alternating-current machinery, the use of electricity for even the heaviest of mine hoisting work may be predicted as a development of the near future.

b. Inclined plane hoists are very largely used on both sides of the Atlantic for veins of considerable dip, or in local folds. Many rope systems are in use for such haulage, viz., simple haulage with single or double drum; continuous rope; and main and tail rope. In all electricity may be applied with a varying advantage, depending upon the location of the plane with reference to the surface power plant. For local dips, occurring at some distance from the surface, it is readily seen

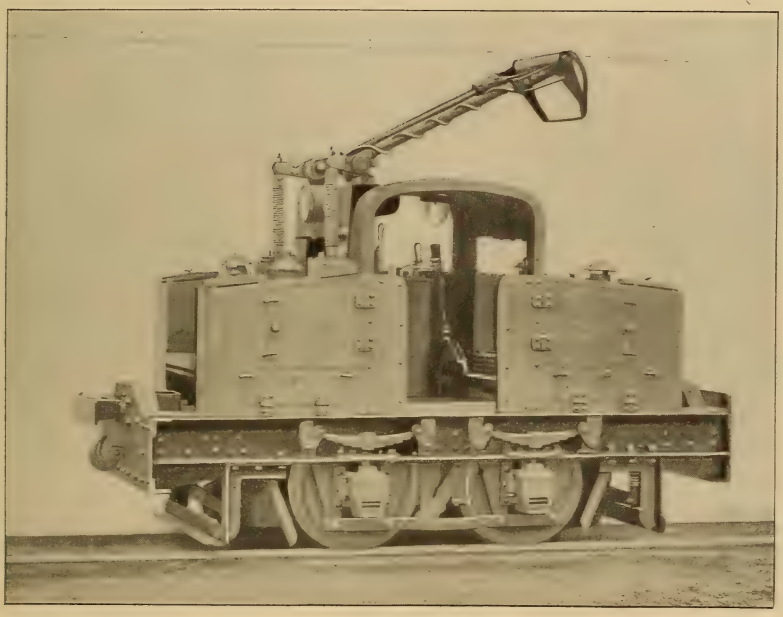


AN EARLY DESIGN OF THE JEFFREY MFG. COMPANY, OF COLUMBUS, OHIO, U. S. A. THIS LOCOMOTIVE IS IN ACTIVE SERVICE TO DAY IN THE MINES OF THE UPSON COAL MINING COMPANY, AT SHAWNEE, OHIO

that the transmission of power through electric conductors offers many advantages over a system of pipes for conveying air or steam, and, as a matter of fact, electricity has already been considerably applied in this class of work.

c. For main entry haulage, with light grades, locomotives enter into competition with rope or animal haulage systems, and are rapidly superseding the latter two forms. This is especially the case for the long-distance haulage occasioned by rapid working in mines of the bituminous coal class where the cost of keeping rope, sheaves, etc., in repair, and the power consumed in friction rapidly increase with the length of run or a departure from a straight line in direction of the entry; while animal haulage has the serious objection of slowness and limited capacity under such conditions.

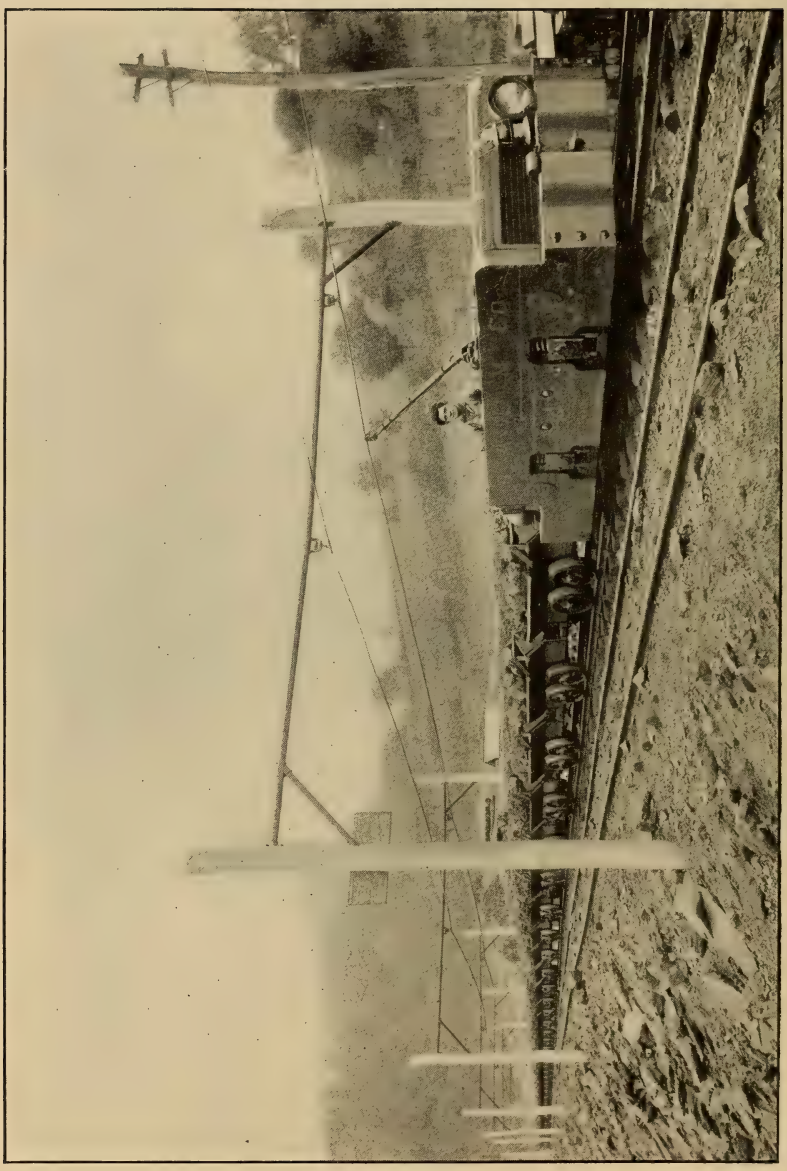
d. "Room" haulage is special, and must be dealt with in various ways in accordance with the local situation. The "rooms" are the lateral workings from the cross headings, and from them the greater part of the mineral is taken. As their location in reference to the runways is variable and constantly changing and the distances are short, haulage in them may be generally done to best advantage by animal power or by men, if approximately level; or by self-acting ropeways, if the grades are 10 per cent. or more in favour of the loads. Special locomotives have occasionally been employed for room work, these being electric and carrying their source of power in the shape of a storage battery. As the apparatus is of a delicate nature, however, the use of such locomotives can be recommended only in special cases and where expert supervision is obtainable.



A TWO-MOTOR LOCOMOTIVE BUILT BY THE ELEKTRICITÄTS-AKTIENGESELLSCHAFT, FORMERLY SCHUCKERT & CO., NÜRNBERG, GERMANY

e. Surface haulage problems must also be treated in accordance with local conditions. In "drift" mines, the locomotive employed for underground work generally hauls its train to the tipple without breaking; in other cases the tipple is reached by a rope inclined plane, for which electric driving is especially useful.

The auxiliary uses for power in mines are also important, such as for ventilat-



A MODERN 13-TON BALDWIN-WESTINGHOUSE LOCOMOTIVE AT THE COLLIERIES OF THE BERWIND-WHITE COAL MINING COMPANY AT WINDBER, PA., U. S. A.

ing fans, pumps, coal cutters, and lighting. For these electricity is eminently suitable.

From the foregoing it is apparent that the economical application of mechanical power to the various uses in a large mine is a study of much importance, and that a very flexible distributing agency is essential. The various means at the disposal of the engineer are:—rope transmission, which is limited both in working distance and adaptability; steam, which can be applied to stationary motors near the surface only, by reason of losses from condensation, and in special cases for locomotives; compressed air; and electricity.

THE POWER HOUSE AND YARD AT THE WINDBER COLLIERIES, SHOWING OVERHEAD TROLLEY CONSTRUCTION FOR SWITCHING YARDS

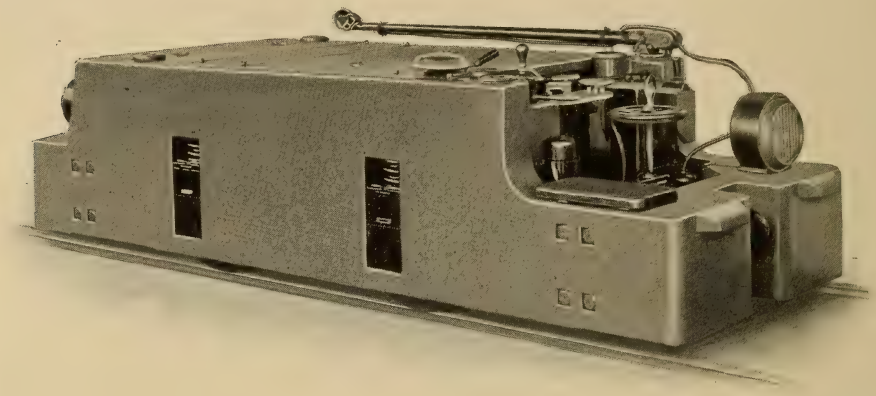
Compressed air has many points of advantage for mine use. The apparatus is simple, requires little skilled attention, and is especially well adapted for such machines as coal cutters, where rough handling makes mechanical strength and simplicity desirable. Compressed air also assists mine ventilation in some small degree. The most serious objections to its use are the extensive network of pipes needed and its poor economy. The maintenance of pipe lines is an expensive matter, as mine water is generally destructive to them.

Electric motors are both durable and efficient, and as a medium for conveying power to a distance electricity has many advantages over the other agencies mentioned in respect to flexibility and economy. As the result of increase in extent and forcing of the output of the bituminous coal mines of America the old and reliable mule is rapidly being superseded. Mule haulage, however, is still very usual in the anthracite regions and in the mining of other minerals where waggons are to be hauled only short distances to the foot of a shaft.

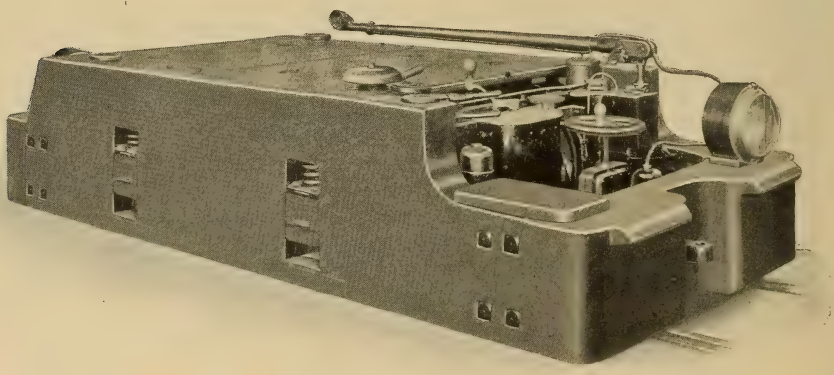
The objections to mules for main entry haulage are the limited capacity of each unit, the considerable size of the gangways required, and the heavy depreciation of the outfit. Mules are to be had in various sizes from 48 inches to 63 inches in height, the average size being 56 inches. They weigh from 700 to 1200 pounds each, and will pull in all-day service about one-seventh of their weight, or, for short periods, one-fifth of their weight. Thus, a 56-inch

mule, weighing 900 pounds, will exert about 130 pounds pull at the waggon draw-bar on a level track and at a speed of one and one-half to two miles per hour. Roughly speaking, a mule will exert about the same pull per pound of its weight as that of an electric mine locomotive. The depreciation of mules in severe mine service is very heavy, being from 20 to 30 per cent. per annum, and their first cost is high, often as much as $125 (£25) each. In actual mine service it is found that a 10-ton locomotive will displace, on the average, 15 mules; or, taking into account the higher speed of the locomotive, its output will be equivalent to that of thirty mules.

The compressed-air locomotive is a useful and efficient machine, and in mines subject to explosive gases it represents the only admissible form of locomotive haulage. Its mechanical simplicity and the fact that it is a self-contained machine, carrying energy stored in tanks, are strong points in its favour. Its disadvantages are limited range of action before recharging is necessary, considerable bulk, and limited tractive power for emergencies. A comparison of the important dimensions and the maximum and ordinary performance



A MODERN 10-TON, 30-INCH LOCOMOTIVE BUILT BY THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK



A STANDARD 8-TON LOCOMOTIVE OF THE SAME MAKE

COMPARISON OF AIR AND ELECTRIC LOCOMOTIVES ON 36-INCH GAUGE TRACK.

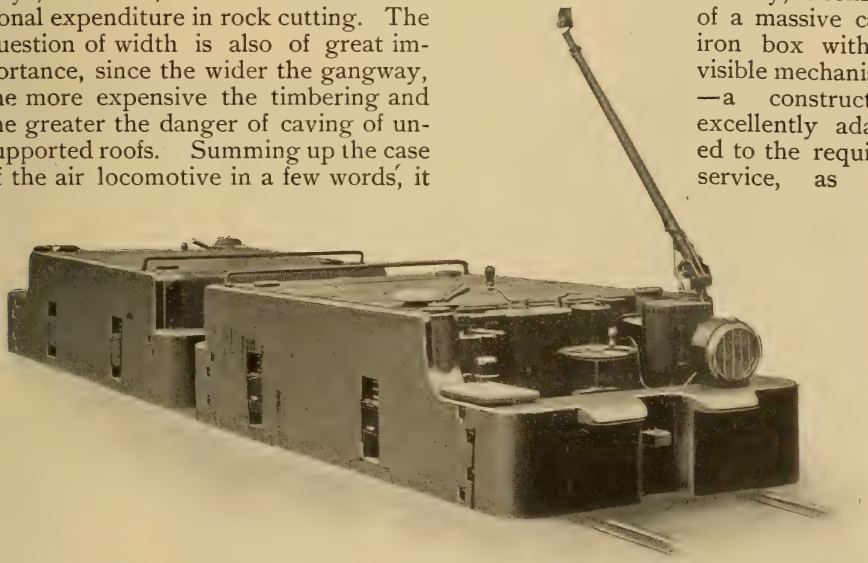
	Small		Large	
Dimensions:	Air	Electric	Air	Electric
Length	12′ 6″	10′ 0″	17′ 0″	12′ 0″
Height	5′ 3″	3′ 0″	5′ 8″	3′ 4″
Width	6′ 0″	3′ 6″	6′ 2″	4′ 8″
Area of cross section	31.5 sq. ft.	9.5 sq. ft.	35 sq. ft.	14 sq. ft.
Maximum tractive effort	1,600 lbs.	1,600 lbs.	4,000 lbs.	6,000 lbs.
Distance run at maximum T. E	3,800 ft.	20,000 ft.	4,100 ft.	15,000 ft.
Normal tractive effort	1,280 lbs.	1,200 lbs.	3,200 lbs.	4,300 lbs.
Distance run at normal T. E.	7,600 ft.	Indefinitely	8,000 ft.	Indefinitely

GENERAL DIMENSIONS OF ELECTRIC MINE LOCOMOTIVES FOR 36-INCH GAUGE TRACK

Weight	Height	Length	Width	Speed m.p.h.	Maximum Tractive Effort	Rated Draw-Bar Pull on Level Track
7,500 lbs.	32 in.	10 ft.	42 in.	6 to 10	1,200 lbs.	900 lbs.
10,000 "	32 "	11 "	45 "	"	1,750 "	1,300 "
15,000 "	34 "	11 "	47 "	"	2,800 "	2,100 "
20,000 "	36 "	12 "	55 "	"	4,000 "	3,000 "
26,000 "	36 "	12 "	56 "	"	5,700 "	4,300 "

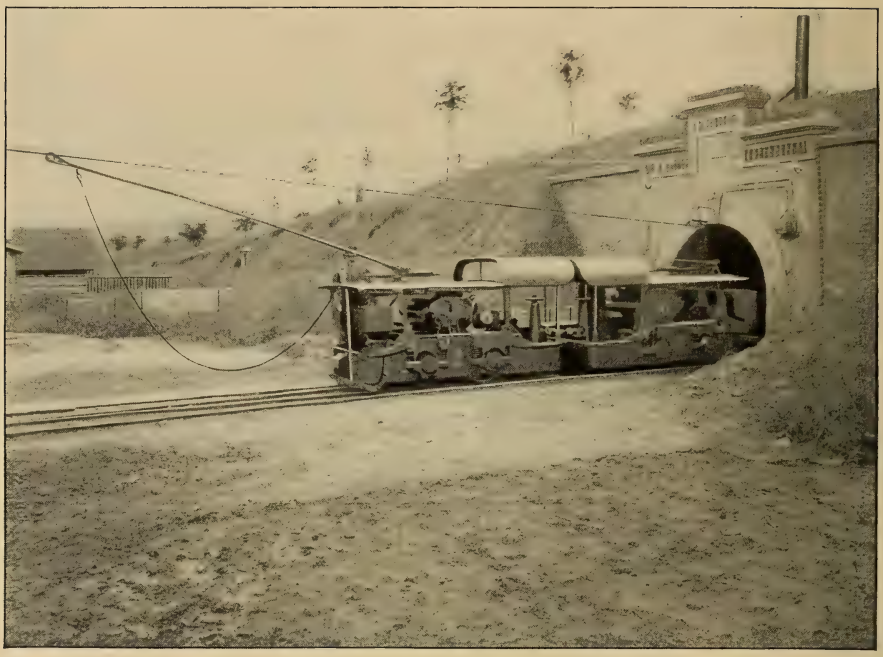
of air and electric locomotives for heavy work on the ordinary coal mine track gauge is given in the table on this page. It is seen that in width the air locomotive is 25 per cent., and in height, 75 per cent. greater than the electric; or, in cross-sectional area, they are as two to one about. In many districts the coal veins are only from 2 to 3 feet thick, and lie between rock strata of considerable hardness; every inch additional height required for the gangways, therefore, means a serious additional expenditure in rock cutting. The question of width is also of great importance, since the wider the gangway, the more expensive the timbering and the greater the danger of caving of unsupported roofs. Summing up the case of the air locomotive in a few words, it may be said that its use should properly be restricted to mines subject to firedamp, or in thick-seam mines where the runs are short, the work light, infrequent, or of a special nature.

The electric locomotive, considered as a machine, has many points in its favour for mine use. For a given hauling capacity it is by far the most compact of all forms of motive power; it is simple in construction and convenient in operation. Externally, it consists of a massive cast-iron box without visible mechanism,—a construction excellently adapted to the required service, as the



A DOUBLE LOCOMOTIVE BUILT BY THE GENERAL ELECTRIC COMPANY.

THESE TWO LOCOMOTIVES, OF 13 TONS EACH, ARE COUPLED MECHANICALLY AND ELECTRICALLY, AND ARE OPERATED AS ONE LOCOMOTIVE FROM ONE CONTROLLER. THE PRIMARY LOCOMOTIVE HAS A FOUR-MOTOR CONTROLLER AND THE SECONDARY LOCOMOTIVE HAS A TWO-MOTOR CONTROLLER, SO THAT THEY MAY AT ANY TIME BE OPERATED AS SEPARATE LOCOMOTIVES

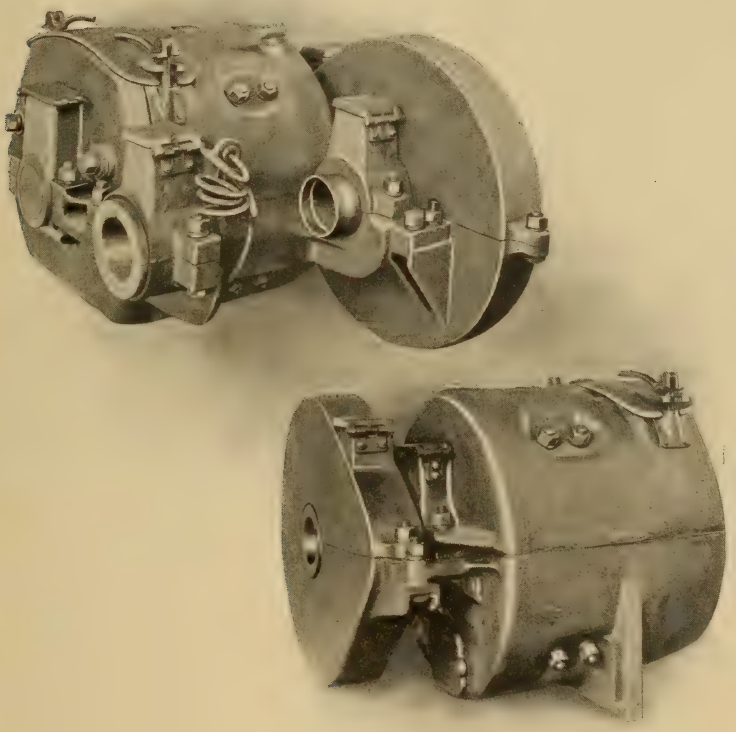


A MINE LOCOMOTIVE AT PALFALVA, ETTES, HUNGARY, BUILT BY MESSRS. GANZ & CO., BUDA-PESTH

THIRTEEN-TON GENERAL ELECTRIC COMPANY LOCOMOTIVES IN THE WOODWARD COAL MINES, AT KINGSTON, PA., U. S. A.

frame serves to give the machine the necessary weight and protects the mechanism against injury in case of derailment or otherwise in rough mine service.

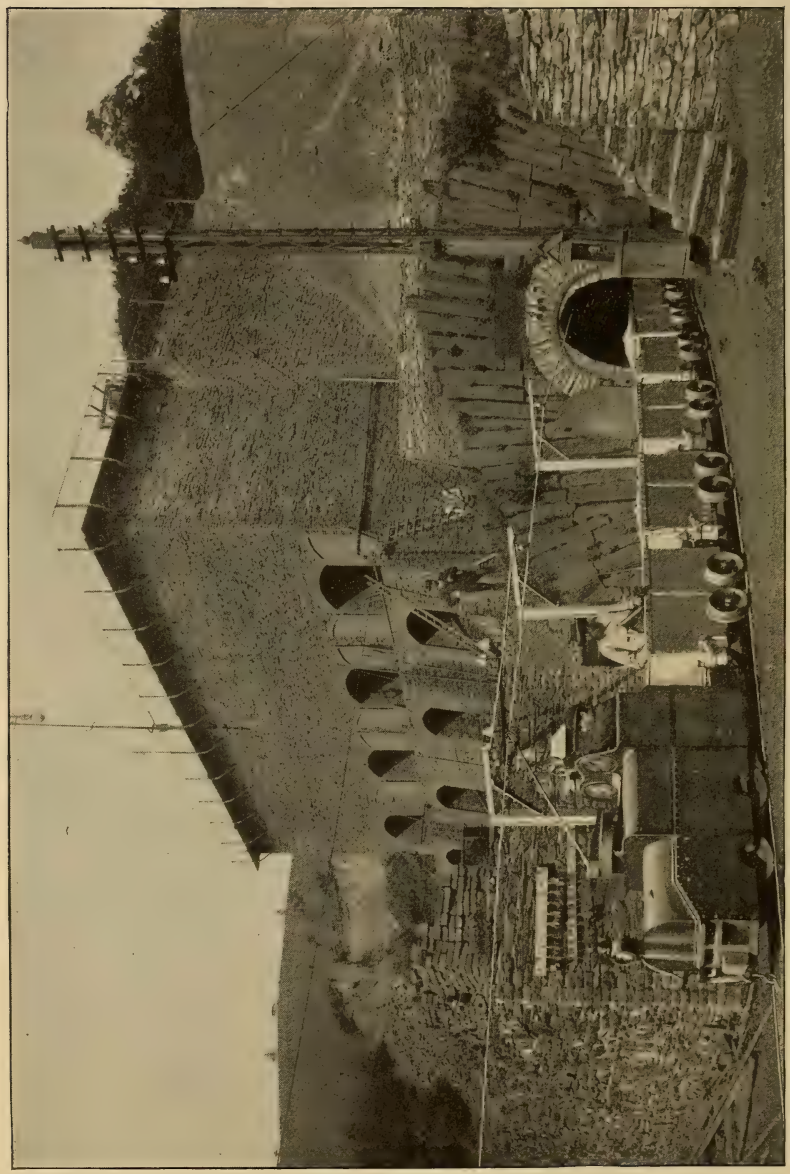
The locomotive is usually mounted on four wheels, giving a short wheel-base to pass sharp curves, and the motive power is developed by two railway-



MODERN ELECTRIC MINE LOCOMOTIVE MOTORS. WESTINGHOUSE TYPE

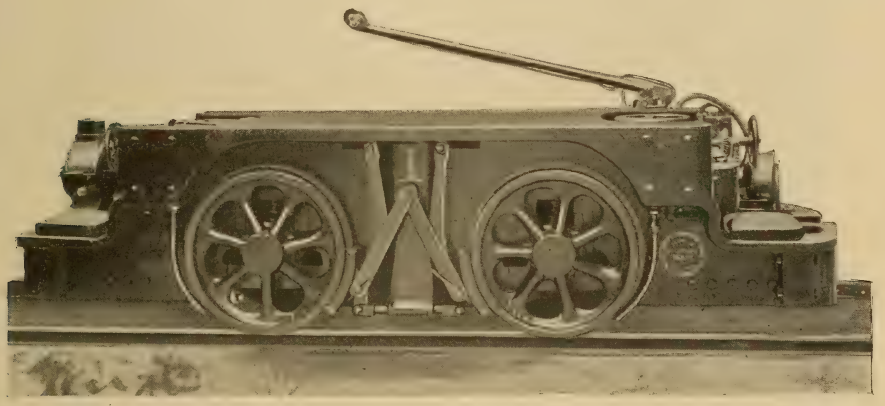
type electric motors, one of which is geared to each axle. The controlling mechanism, consisting of a current controller, a powerful hand-brake, sanding devices, etc., are compactly grouped at one end and within convenient reach of the motorman. The general dimensions and performance of the various standard sizes of mine locomotives are concisely given in the table on page 331. These sizes were adopted as the result of careful study of mining conditions, and are listed by various builders in America as regular commercial machines. The European design of mine locomotive differs considerably from American practice, as will be seen from the several illustrations in these pages, and its complexity and lack of compactness would make it unsuitable for general mining conditions in the United States.

A determination of the proper locomotive equipment for a given mine is dependent upon a variety of factors, such as the maximum grade over which it is desired to operate, the condition of the track, character and condition of the waggons, and a general knowledge of the haulage scheme, such as length



A LOCOMOTIVE BUILT BY THE ALLGEMEINE ELEKTRICITÄTS GESELLSCHAFT, BERLIN

of haul and output desired per locomotive. The importance of all these considerations will be apparent when it is observed that mining conditions necessitate extremes for grades and curvature, and that the waggon resistance is far greater than that found on surface railways. Thus mine grades are frequently as much as 4 to 6 per cent., and curves as short as 15 feet radius; waggon resistance varies generally between thirty and sixty pounds per ton weight, never falling below twenty pounds, and frequently exceeding sixty with badly worn, loose wheels. The rails are generally light and in poor condition, so that the adhesion is seldom better than one-sixth of the weight on drivers for tractive effort.

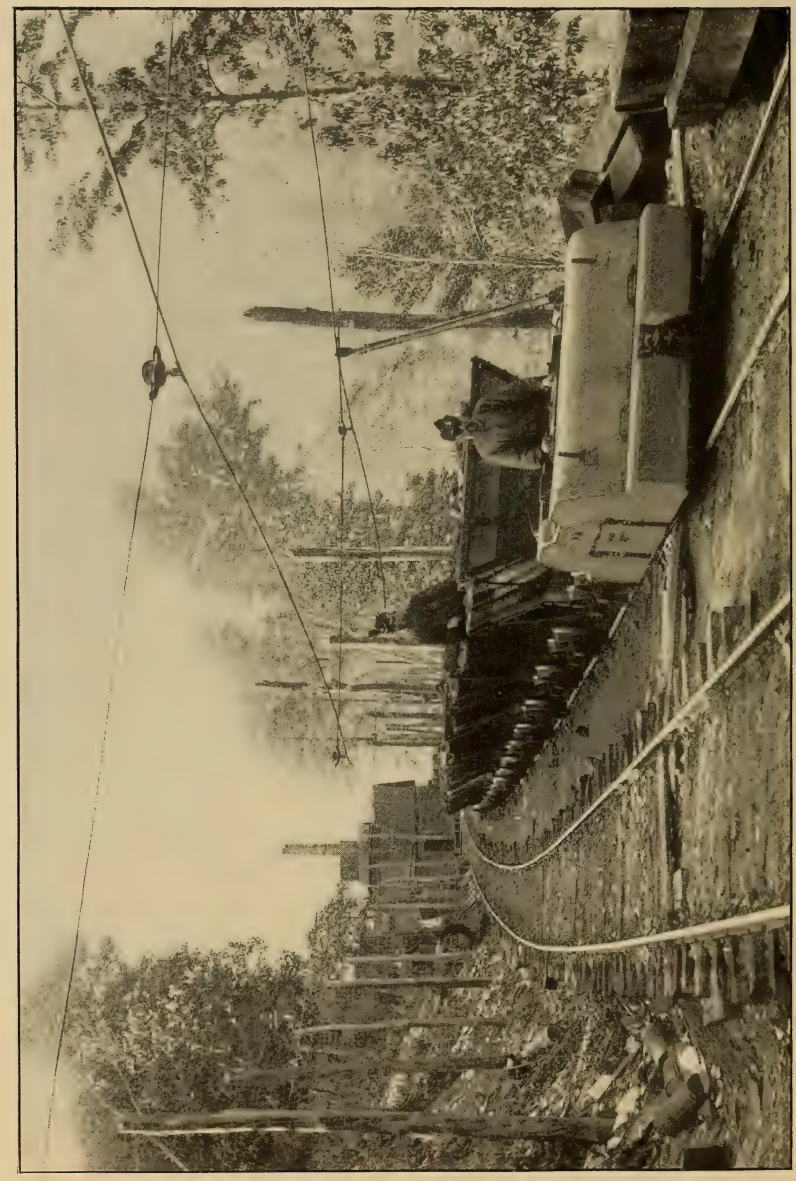


A BALDWIN-WESTINGHOUSE DOUBLE-END DESIGN

When the above conditions have been ascertained, the size and number of locomotives required to handle the mine output can be determined. But it should be understood that the capacity of a given electric locomotive is dependent upon the maximum and the average work required of its motors in a given time. In other words, a certain hauling power can be furnished continuously, but this will be much below the maximum capacity of the locomotive on short, heavy grades. This limitation arises from the heating effect of an electric current upon the motor windings, an effect which is cumulative and cannot be dissipated faster than at a certain rate. In average mine service the work required of a locomotive is variable, and where no unusual conditions prevail it has been found safe to assume that the full tractive effort will not be required for more than 40 per cent. of the time. The tabulated rating of locomotives is based upon this assumption.

The actual tonnage of product which can be handled per locomotive per day varies, of course, with the local conditions and size of locomotive. In many mines the same locomotive is employed for collecting, main haulage and switching, and the work done is subject to much variation on account of time lost in making up the trains. In large mines the main entry haulage is a distinct operation, and in such cases a 10-ton locomotive will readily handle to the tipple from 800 to 1000 ton-miles of loading in an eight-hour shift.

In mining work a consideration which generally does not receive the attention which its importance deserves is the gauge of the track. It frequently results, therefore, that an adequate mechanical haulage plant is an impossibility on account of the limitations of an unsuitable track gauge which was in use with the mule-haulage system. If the track curves are properly laid out, there is no practical advantage in the extremely narrow gauges found in some mines; thus, mine waggons and locomotives will readily pass curves of from



A MODERN 14-TON ELECTRIC MINE LOCOMOTIVE BUILT BY THE JEFFREY MFG. COMPANY, COLUMBUS, OHIO, U. S. A.

20 to 25 feet radius on a 36-inch gauge track, or curves of 15 feet radius on a 30 inch gauge. Electric locomotives of good design have the following limitations in power for various track gauges:—

24-inch gauge,	500	lbs.	draw-bar	pull	on	level.
30	"	"	2,000	"	"	"	"	"
36	"	"	4,000	"	"	"	"	"

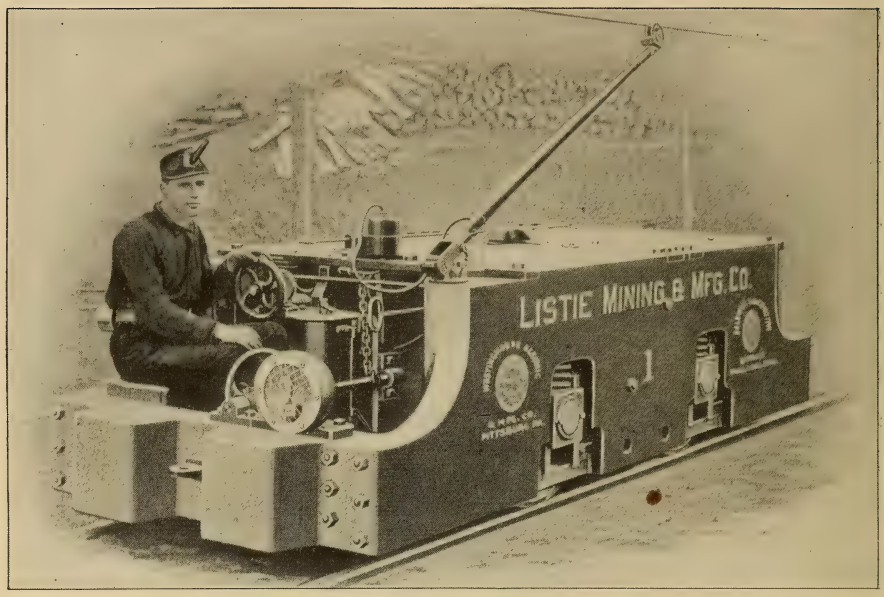
The advantages of the wider gauges are, therefore, apparent, and it is advisable in all large mines to adopt a 36-inch gauge as standard.

As connected with this subject, the weight of rail is of importance, especially for mechanical haulage. Light rails, while cheap in first cost, are expensive both as to wear and tear of track and equipment, and the narrow rail heads materially reduce the hauling power of the locomotive. A convenient rule, which has been in use for many years by the Baldwin Locomotive Works, specifies that the minimum weight of rail must be ten pounds per yard for each one ton weight on one wheel.

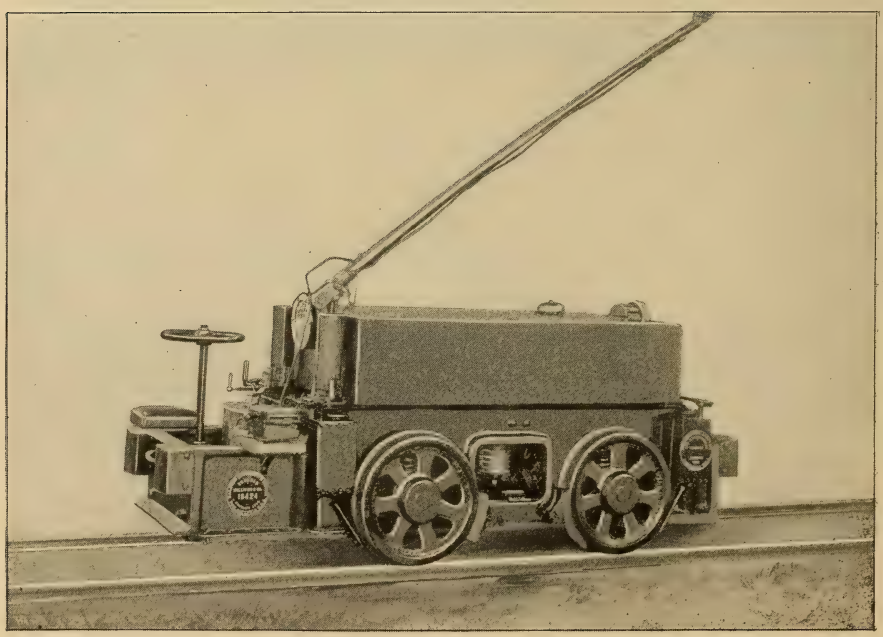
As illustrating the results which may be accomplished with the aid of electric locomotives, it may be interesting here to cite the case of the Eureka collieries of the Berwind-White Coal Mining Company, in Somerset County, Pennsylvania. These are among the largest in America, comprising about 70 square miles of coal territory, with a seam averaging about 4 feet in thickness. The deposit is worked through several separate drift openings, scattered over an area of about four square miles, and the present output is about 12,000 tons per day. Every ton is mined by machinery, and is delivered to the tipples by electric locomotives, of which the company have about forty in service. On account of the thin seam, the waggons are small, holding 2300 pounds each. The average round trip is 10,000 feet, and the average number of tons of coal delivered to tipple against a 1½-per cent. grade by each 13-ton locomotive is 375 in an eight-hour shift. The locomotives gather at the seam partings, the loads being delivered at these points by man-power from the headings, and make them up into trains of twenty-five waggons. Each tipple is equipped with special dumping machinery to handle 1600 waggons daily, and the system is so perfectly arranged that 400 waggons can, if necessary, be dumped per hour.

A 20-TON, THREE-MOTOR LOCOMOTIVE BUILT BY THE JEFFREY MFG. COMPANY, COLUMBUS, OHIO. THREE MOTORS ON INDEPENDENT AXLES

Each working has its own power plant, with generators and compressing machinery, and the electric system from the various plants is interconnected for use when desired. The trolley wires carry current for the locomotives at 500 volts pressure, and are neatly and substantially erected. The main trolley current is also used for lighting the mines with incandescent lights, five being placed in series across the circuit.



A 100-H. P. BALDWIN-WESTINGHOUSE LOCOMOTIVE



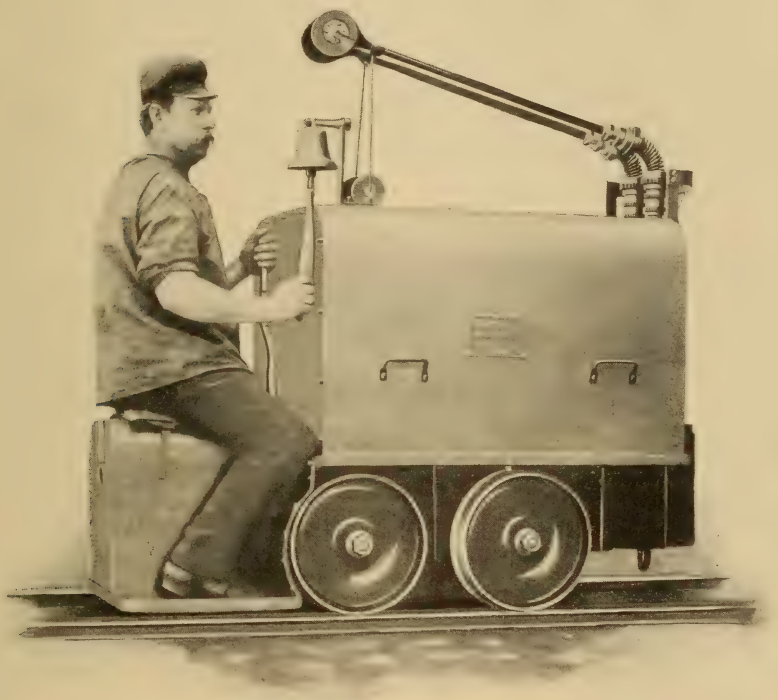
AN ELECTRIC STORAGE BATTERY BALDWIN-WESTINGHOUSE LOCOMOTIVE. THE TROLLEY POLE ATTACHMENT IS USED FOR CHARGING THE BATTERY WHILE THE LOCOMOTIVE IS USED ON A TROLLEY CIRCUIT, THUS GIVING IT CONTINUOUS SERVICE WITHOUT DELAY FOR BATTERY CHARGING IN THE USUAL WAY

The entire plant reflects great credit upon the business sagacity and enterprise of the company. One of the mines was first developed by mule haulage combined with a rope hoist in the main heading, which had a 2½ per cent. dip for 1000 feet length. By this system, using seven mules and horses, and seven drivers, in addition to the hoist engineer and rope rider, they were able to haul 200 tons daily at a cost of 10 cents (5d.) per ton. In this same mine they now have abandoned the hoist and mules, and with one 13-ton electric locomotive haul 480 tons of coal and fifty waggons of rock daily, at a cost of 1.6 cents (0.8d.) per ton of coal.

One of the most important problems to be solved in connection with the installation of an electric mine haulage plant is that of the proper system of generating and distributing electricity. Electric locomotives are operated by means of the overhead trolley system of wiring, similar to that in common use for street railways. On account of the restricted head-room and the frequent changes and extensions of the haulage system, mine wiring is a source of more or less difficulty, especially as it is generally done in a temporary and slipshod manner.

For short-distance haulage the trolley wire alone is sufficient to carry the current from the power house and for the locomotive contact conductor. This wire, which is of hard-drawn copper, is supported from the roof by clip hangers, at an average distance of 30 feet; these are secured in the rock of the roof by driving and expanding slotted pipes in holes, and to these are secured the insulating piece of the hanger.

For heavy and long-distance work additional copper wires must be provided for feeders. These should be



A SINGLE-MOTOR LOCOMOTIVE BUILT BY THE BRITISH SCHUCKERT ELECTRIC CO., LTD., LONDON, AND THE ELEKTRICITÆTS-AKTIENGESELLSCHAFT, FORMERLY SCHUCKERT & CO., OF NÜRNBERG, GERMANY

thoroughly insulated and secured in places where they are not liable to be accidentally handled As insulating covering is subject to rapid deterioration in mines, bare wire is generally used, and preferably located in abandoned air or gangways.

The systems in use for generating the electricity differ in important particulars, in accordance with the extent of the plant and the uses for which power is desired. The two general methods are:—

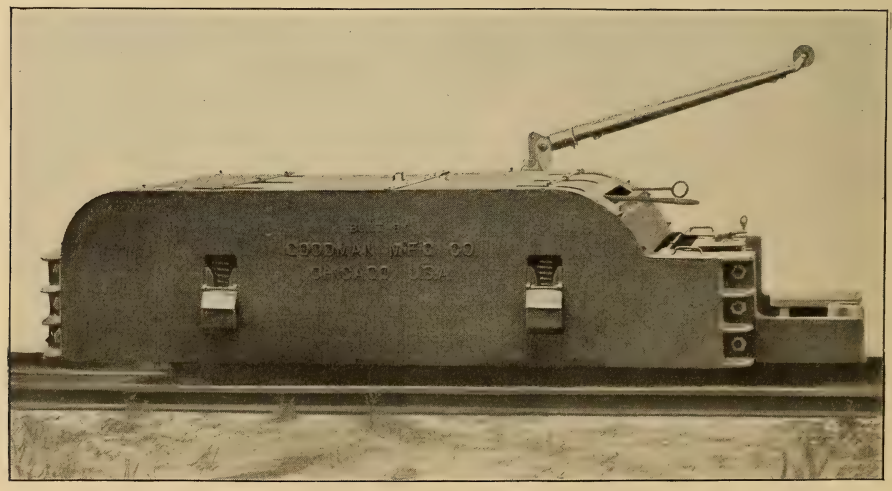
a. Direct current for all power and lighting purposes;

b. Alternating current for lighting and stationary motors, and direct for locomotives.

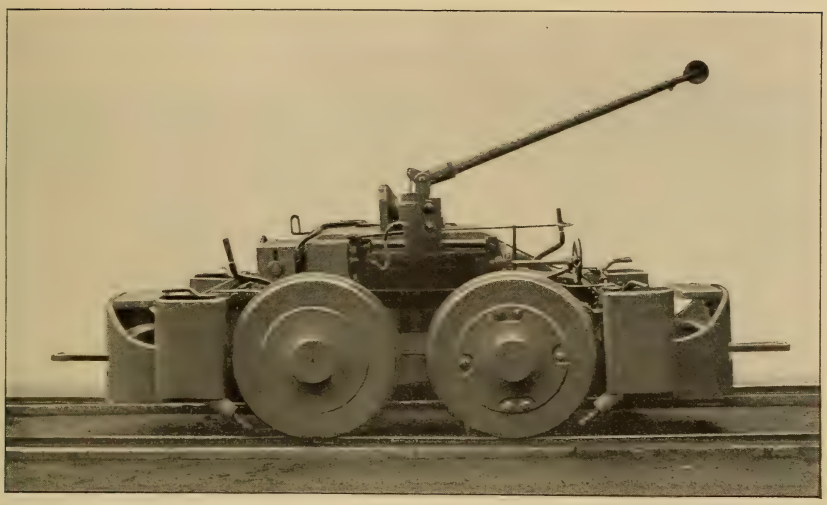
The first-mentioned is the simpler in generating plant and mine wiring; the second is the more flexible in distributing power over considerable areas, and permits the use of a very desirable type of stationary motor for pumping, hoisting, and other work. The two systems may, in certain cases, be combined so that both alternating and direct current are furnished and distributed at different pressures from the same generator. This system is special, and the description is of such a nature as to be outside the scope of this article.

In planning a system the element of safety is of great importance, because of the difficulty of protecting men and animals against accidental contact with wires in the confined spaces of a mine. The ordinary precautions, suitable in overground work, of insulating the wires with a protecting covering, cannot be safely relied upon underground where the dampness and corrosive elements in mine water make it wise to treat the wires as if they were uncovered. This fact, of course, greatly limits the working voltage of the current, and this, again, practically determines the system and its cost.

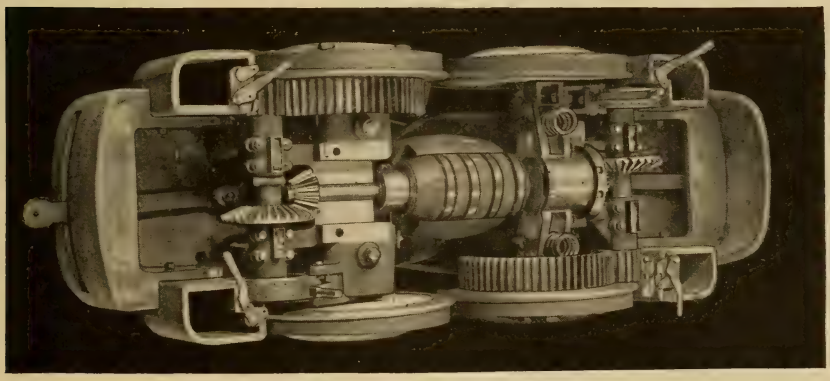
The two pressures in general use for motors are about 250 and 500 volts. In dry situations it may be said that neither are fatal to human life; in damp places, however, such as mines, 500 volts are dangerous, and, under certain circumstances, may be fatal; 250 volts, on the other hand, are not, and would be employed exclusively were it not for the consideration of first cost. As illustrating the difference between the two pressures in this respect, it may be pointed out that a 13-ton locomotive, hauling full load, may be operated for a distance of about three miles from the power house by means of a 500-volt circuit through a single No. 0000 diameter trolley wire, whereas with 250 volts this wire would suffice for about one mile only, and for a three-mile circuit sup-



LATEST TYPE OF TWO-MOTOR LOCOMOTIVE BUILT BY THE GOODMAN MFG. CO., CHICAGO, ILL., U. S. A



A SINGLE-ARMATURE LOCOMOTIVE BUILT BY THE GOODMAN MFG. COMPANY



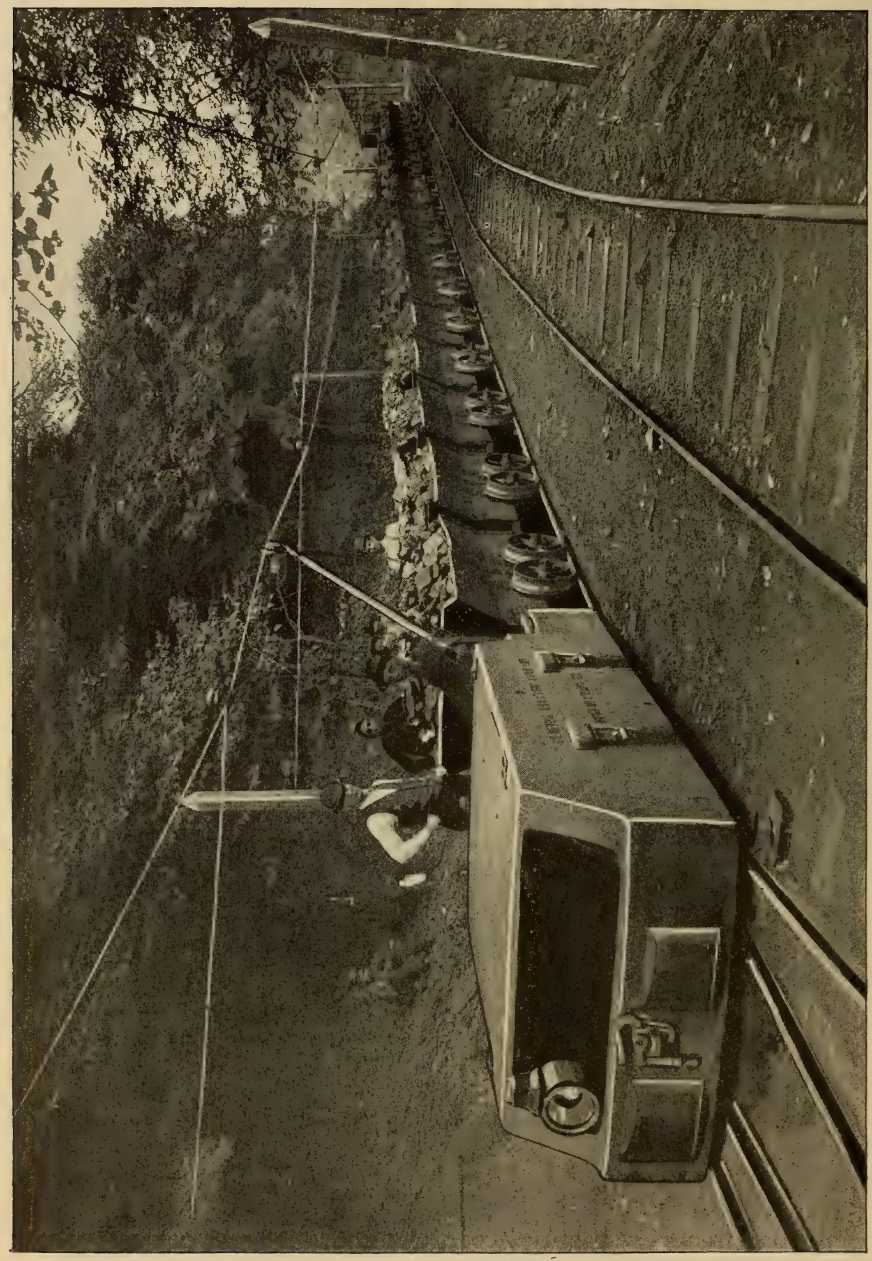
TOP VIEW, SHOWING THE GEARING

plementary feed wires would have to be installed, of several times the section of the trolley wire. The difference in cost of copper alone for the three-mile circuit is, therefore, about $4000 (£800) in favour of the 500-volt system. Where power is needed for other purposes along the line, it is readily seen that the investment in copper for the low-pressure system may run into high figures.

Both the direct and the alternating-current systems are adapted to lighting and stationary motor uses; but the direct only is suitable for locomotives, so that, where all forms of power are required, this, or a combination system, must be employed.

Generally speaking, the following conclusions may be drawn from the above:—Small mines should employ the simplest possible system, both for power plant and wiring. In these cases economy in first cost, reliability, and safety in operation when under the supervision of men of limited technical experience are essential. Such a system consists of a direct-current generator and the distribution of current at 250 volts pressure.

In extensive mining plants the power system should be planned with the same attention to good engineering practice as is found justifiable in any undertakings of similar magnitude and perma-



ONE OF THE LOCOMOTIVES OF THE BRITISH THOMSON-HOUSTON COMPANY, LTD., LONDON

nency. In such plants economy of operation, flexibility in extension, and adaptability to various uses are of great importance, and the accompanying complexity does not introduce operating difficulties when the system is under the supervision of competent special attendants. The planning of such cases should, however, be treated as special problems and entrusted to engineers versed in such matters. By the use of a combination alternating-direct system all the advantages of simple alternating motors for auxiliary uses, economical high-tension distribution, and a low and safe direct-current locomotive haulage system may be obtained, thus rounding out a complete modern power system for all the principal mine operations.

The saving to be effected by the introduction of electric haulage in a mine using mules should rightly include an estimate of the value of increased output and economies following upon decreased cost of cutting entries and the possibility of operating upon heavier grades, as well as the usual items directly chargeable to haulage. These indirect economies vary between wide limits, being greater as the length of haul increases and as the head-room becomes more limited; but they cannot be expressed in general figures. The direct comparison of operating and maintenance costs, however, shows that under the most favourable conditions mule haulage costs at least three times as much per ton of product as electric haulage; and in mines with heavy grades against the loads, mule haulage is often more than five times as expensive. Expressed in figures, the average saving to be expected by the adoption of electric instead of mule haulage is from 4 to 5 cents (2 to 2½d.) per ton of output, and in large mines with heavy grades the saving is frequently as great as 8 cents (4d.) per ton.

Allusion has been made to the adaptability of air locomotives for mine haulage. In a certain case, in the American anthracite coal regions, an air plant was installed under rather favourable conditions for such a system; that is, the vein was thick and the run only about one mile in length. The first cost of this plant, including horse-power, pipe-line, and locomotives, was found to be approximately one-third greater than that of an electric haulage plant for the same conditions, and arose from the greater expense of the pipe line over that of a trolley line. For a longer haulage distance the comparison would, of course, have been much more favourable to the electric system; and the same might be said if the expense of enlarging headings had been necessary. The relative operating expenses of the two systems were estimated to be about 10 per cent. less for the electric than for the air system.

COMPRESSED AIR IN MINING

FOR DRILLING, HAULING, HOISTING, AND PUMPING

By Edward A. Rix

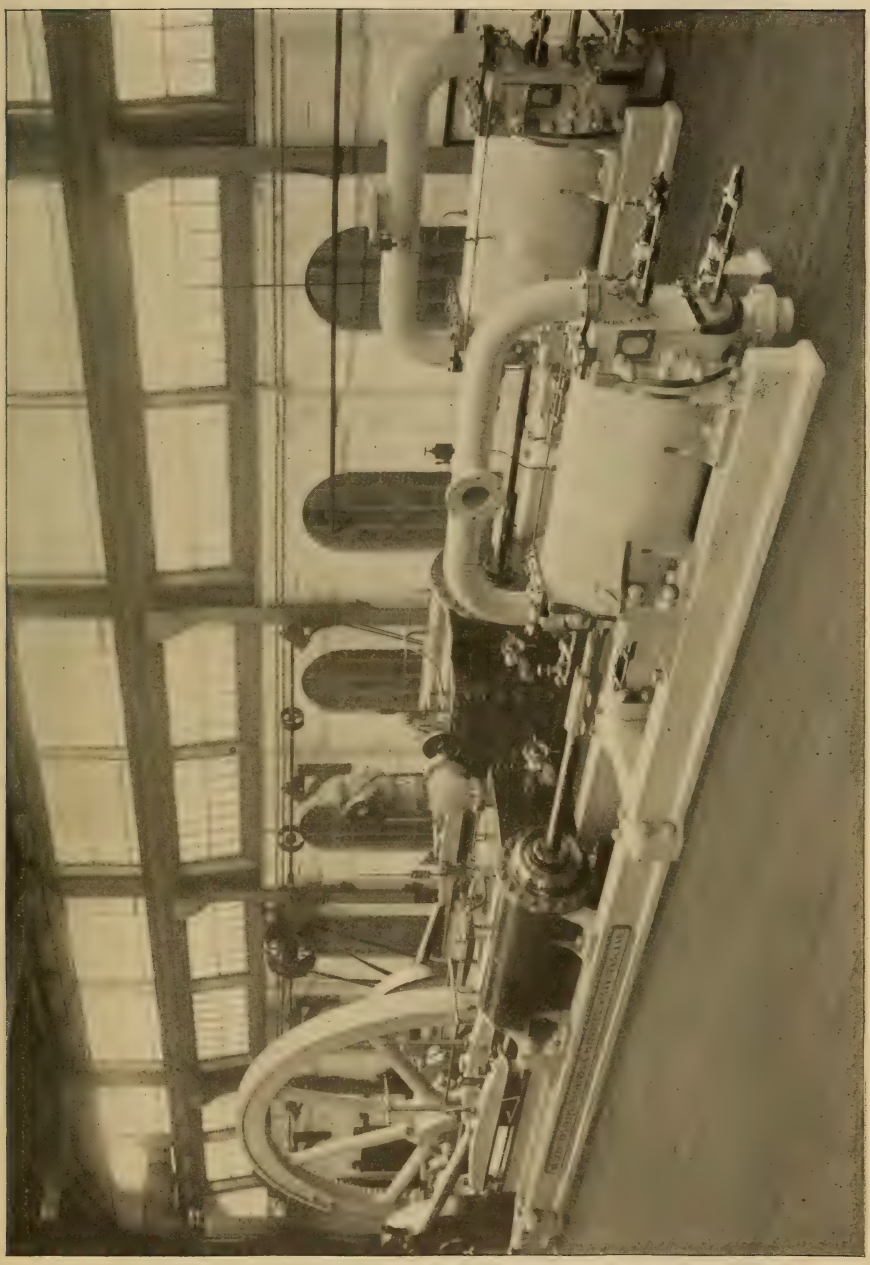
THREE general classes of air compressors are used for mining purposes—those that are steam driven; those that are water driven; and those driven by electric motors. They all may be either simple or compound. The general arrangement of the cylinders is not of great moment; that is to say, it matters little whether the compressor is duplex, cross-compound, tandem-compound, or of any one of three or four combinations, provided that the cylinders are disposed in such a manner that the work of the motor will be a minimum.

The best-known and simplest form of compressor is the so-called straight-line machine in which the air cylinder is directly behind the steam cylinder and one piston rod connects them both. This form of compressor is, as a general rule, not desirable, for economical reasons, for an equipment of more than 50 or 75 H. P., and, for powers up to 150 H. P., should be replaced by a compound machine of a similar type. For larger machines it would seem that a Corliss engine would be better calculated for economy, either simple or compound or compound condensing, according to the power and the opportunity for obtaining condensing water.

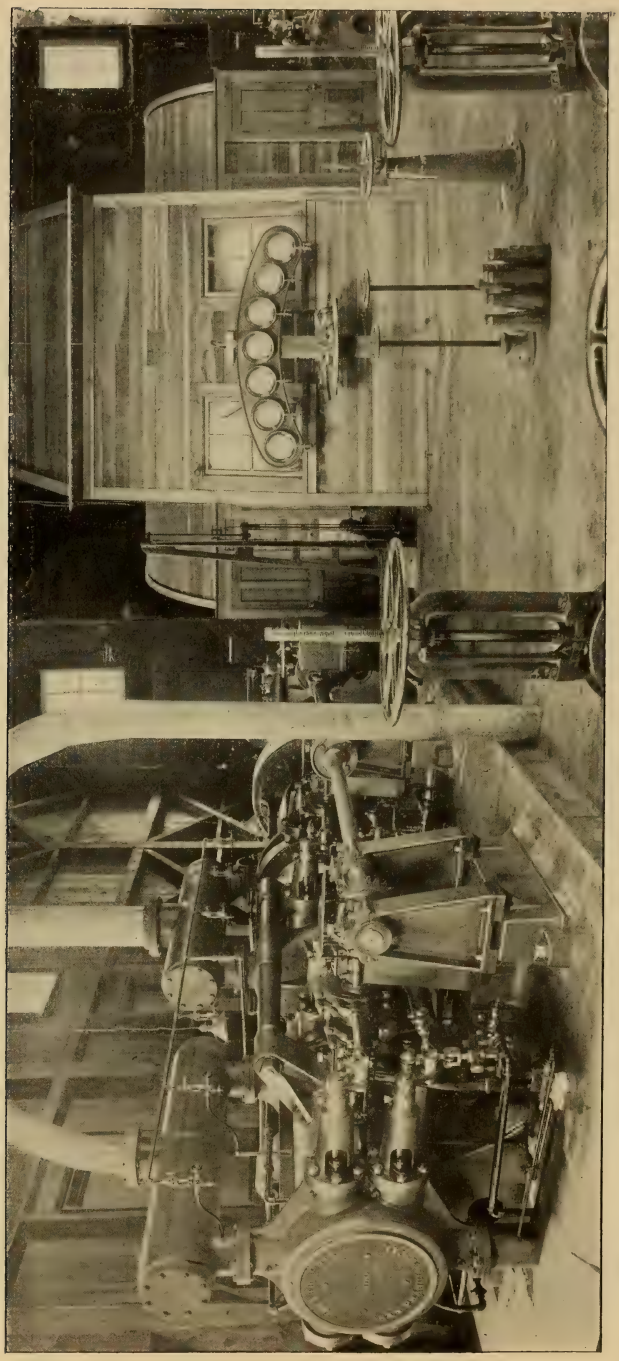
It naturally must be assumed that at this time, when the conservation of power seems to be an important consideration, a mine which has to convert so large a portion of its power into compressed air will do so with economical machines. It seems useless to discard the more expensive fuel and encourage the water-power companies who offer cheaper power, if, after that power has been obtained, no effort is made on the part of the mine management to take advantage of it for the larger powers, and the writer has this fact in view in placing the various kinds of compressors in the order named.

For compressors driven by water-power the simpler forms are plain air cylinders, operated by belt or gearing from impulse water-wheels. This type should not extend beyond 50 H. P., at which point the compound machine should take its place, and no improvement upon this form can be suggested, excepting that, where the opportunity offers, it is always preferable to have the water-wheel direct-connected on the compressor shaft. This practice eliminates many objectionable features, principally the cost of separate foundations, saves space, a separate fly-wheel and the maintenance of belt or gears.

It has been generally assumed that this practice has mechanical limits, within ordinary conditions, but the writer has not found this to be the case. The excessive diameters of these wheels, due to the fact that the number of revolutions should be small, has been an apparent barrier to their employment for heads of water above 500 feet, and the first wheel employed for a head of 700 feet and 100 revolutions, which called for 19 feet in diameter, was undertaken with some hesitation. The ease, however, with which it performed its work, justified the construction, later, of one of 22 feet, following which came



A DUPLEX COMPOUND AIR COMPRESSOR, BUILT BY MESSRS. WALKER BROTHERS, WIGAN, ENGLAND



ONE SIDE OF A DUPLEX COMPOUND AIR COMPRESSOR, INSTALLED AT THE MORNING MINE, MULLAN, IDAHO, U. S. A., BY THE RIX COMPRESSED AIR & DRILL CO., SAN FRANCISCO, CAL. THIS COMPRESSOR IS DRIVEN BY THREE PELTON WHEELS, ONE OF THEM 33 FEET IN DIAMETER, THE LARGEST IN THE WORLD, WORKING UNDER A HEAD OF WATER OF 1400 FEET

one of 25 feet, another of 30 feet, and later still one of 33½ feet, the latter operating under a head of 1400 feet. This wheel has satisfied all expectations.

It can readily be seen that in wheels of this large diameter, where the principal weight is concentrated in the rim, and with a jet under tremendous heads impinging from one or two nozzles upon the buckets, the fly-wheel effect is perfect and a much lighter wheel may be suspended on the shaft to give the same general effect as a heavier fly-wheel. Another advantage in having a direct-connected wheel, where compound compressors are used, lies in the fact that the water-power in the tail race and the spray from it may be used very advantageously for intercooling without using an excessive length of pipes.

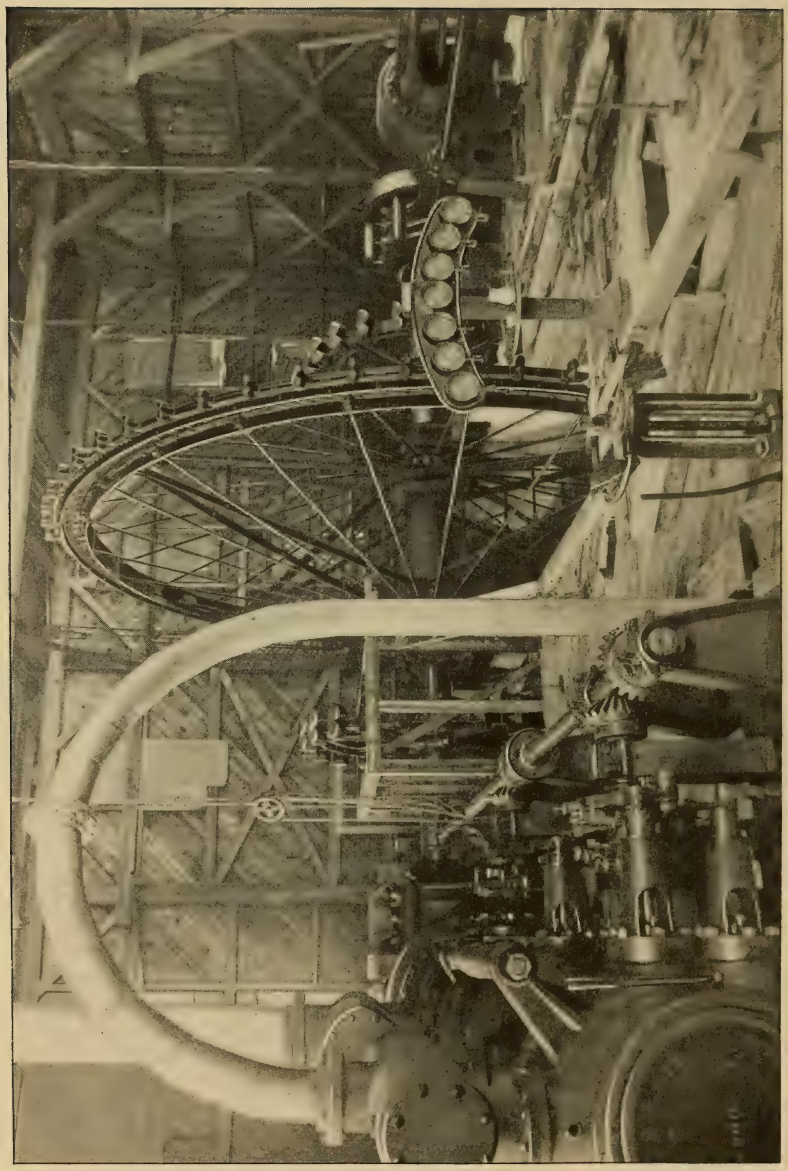
In compressors driven by an electric motor new conditions are encountered. Most of the motors used are induction or synchronous motors, which run at practically constant speed. In the other classes a system of governing can be applied to the speed of the machine for the conservation of power, while with the electrically-driven compressors the speed must be constant and there must be some other means of regulating the duty. This is found in what are termed variable volume machines —that is to say, machines which are so governed that they compress more or less air, depending upon the requirements of a mine. This is generally done, and is eminently successful in handling the quantity of air and at the same time relieving the compressor from undue service. Nothing is more objectionable than the continual blowing off of air from the receiver and nothing is more wasteful of power. In addition to the classes above mentioned, compressors are also driven from line shafting in mills, but these are generally of small capacity; otherwise the uniformity of motion demanded by the mill would be seriously disturbed.

The principal uses for compressed air in a mine are for running rock drills, for shaft sinking, drifting, stoping and upraising, and pumping. It has generally been considered good practice, depending upon the hardness of the material encountered, to use for shaft sinking either the 3⅛, the 3¼ or the 3½-inch drill; for drifting, either the 2¾, 3⅛ or 3¼-inch machines; and for stoping, either the 3-inch, 2¾ or 2¼-inch machines. There are mines that use a 3½-inch drill for stoping, but it would appear to the writer that a smaller size would be more economical.

A ROCK DRILL MOUNTED ON A SHAFT BAR, MADE BY THE INGERSOLL-SERGEANT DRILL CO., NEW YORK AND LONDON

The average shaft drill consumes from 100 to 120 cubic feet of free air per minute, compressed to about 90 pounds; the average drill used in drifting consumes from 70 to 100; and the average drill for stoping consumes from 40 to 70. In general, while holes are drilled very frequently to a depth of 8 feet, they average about 4½ feet, and the size of the hole is such as will permit the use of sticks of powder of from 1 inch to 1½ inches in diameter.

The average work of a rock drill for one shift is from 30 to 40 feet of holes



A CONSTRUCTION VIEW OF THE COMPRESSOR PLANT AT THE MORNING MINE. THE THREE PELTON WHEELS CAN HERE BE SEEN PREVIOUS TO HOUSING IN

drilled. It is generally assumed that a good rock drill will do the work of from six to ten men. It takes from five to twelve horse power to furnish a drill with compressed air, and with the exception of what are known as "Baby" drills, it takes two men,—a machine man and his helper,—to operate a machine.

Air is furnished to the drills through pipes leading from the shaft into the drifts or stopes. In general, these pipes are too small for the work intended. In the average mine, not knowing just how far drifting will be continued, too small a provision is usually made for the diameter of the branch pipes, and often such a pipe, laid in a drift originally for the sole purpose of running rock drills, is tapped to operate a winze hoist, and after that a pump in the winze, and very frequently for operating fan engines, so that often with ninety pounds pressure at the surface, a rock drill will not receive over forty to forty-five pounds in its cylinders. This lessens its proper work to a marked degree and increases the cost of the output of the mine. It always pays, whether operating one drill or more, to put in a pipe of sufficient size to give very nearly full pressure at the drill.

Most of the standard drills are reliable in character and are good enough for performing proper service in a mine. The man behind the drill practically determines how much work the drill will do in a shaft. A poor machine in the hands of a good workman will do more work than if the situation were reversed. For economy in mining a first-class machine man should be given a good drill and one of proper size for its work, and he should be permitted to repair his drill often enough so that the machine will expend its energy upon the rock instead of jumping about on a loose clamp, a worn-out feed screw or loose guides.

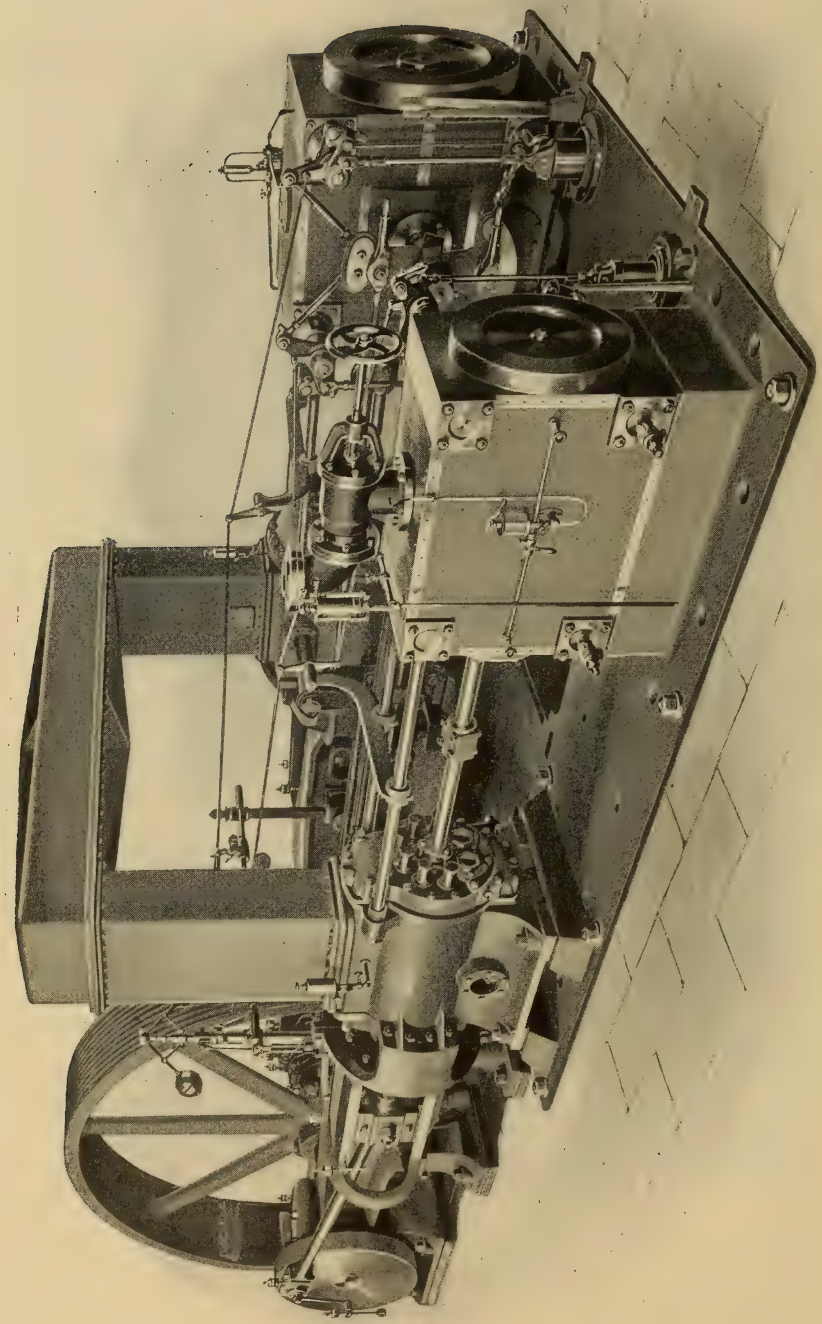
Too often the economy of a rock drill is judged by the amount of repairs it takes, though these may or may not be the fault of the machine; but, in any event, this feature should not be taken into consideration.

From an experience of something like twenty years with drills the writer finds it impossible to make a proper comparison between different kinds of drills operating at different mines, and even in the same mine two different drills should be operated at the same time and in the same drift by equally skilled men in order to permit making a fair comparison. After keeping tabulated lists for a number of years the writer finds that of the standard makes of drills, having the same weight and the same diameters of piston and piston rod, there is practically no difference in cost of repairs per foot of holes drilled during the month. The repairs on a drill are so insignificant with respect to the cost of running the drill that they may be neglected, and one's thoughts and energies should be concentrated on the other features of expense attached to their operation.

One mine that has come under observation and which keeps a very complete record of its operations pays $3 a day for a machine man and $2 for a helper. These wages average 16 cents per foot of hole drilled; the power averages 5 cents per foot of hole drilled; the breakage and repairs are about 0.06 cent per foot, making a total of 21.06 cents per foot. It will be noted that the cost of breakage and repairs is only one-thirty-sixth of the cost of drilling the holes, or less than 3 per cent, which may be neglected and attention given to the more important elements of wages and the capacity of the drill.

In the above record the average is 38 feet of holes per shift per drill. There were two shifts per day, making 76 feet per day, or 2280 feet per month, for one drill. The cost of breakage and repairs on these drills during the month, at 0.06 cent per foot, would be $13.68, and this is about what it ought to be.

Now if the repairs and breakages are $13.68 for drilling 2280 feet of rock, then in order to offset this expense by extra service of the drill it would be necessary to drill during the month only 65 feet additional, at 21 cents per foot. If it is desired to gain 65 feet in a month where 2280 feet are being drilled,



A RAND-CORLISS AIR COMPRESSOR WITH CROSS-COMPOUND STEAM AND CROSS-COMPOUND AIR CYLINDERS AND INDEPENDENT JET CONDENSER, BUILT FOR THE GOLD COIN MINING CO., OF VICTOR, COLORADO, U. S. A., BY THE RAND DRILL CO., OF NEW YORK

it would mean that there would have to be a gain on each amount of holes drilled of one-third of an inch, or, practically, if another machine man or another drill were substituted and either the man or the drill advanced the record one-third of an inch to the foot, it would entirely cover the cost of keeping the drill in repair.

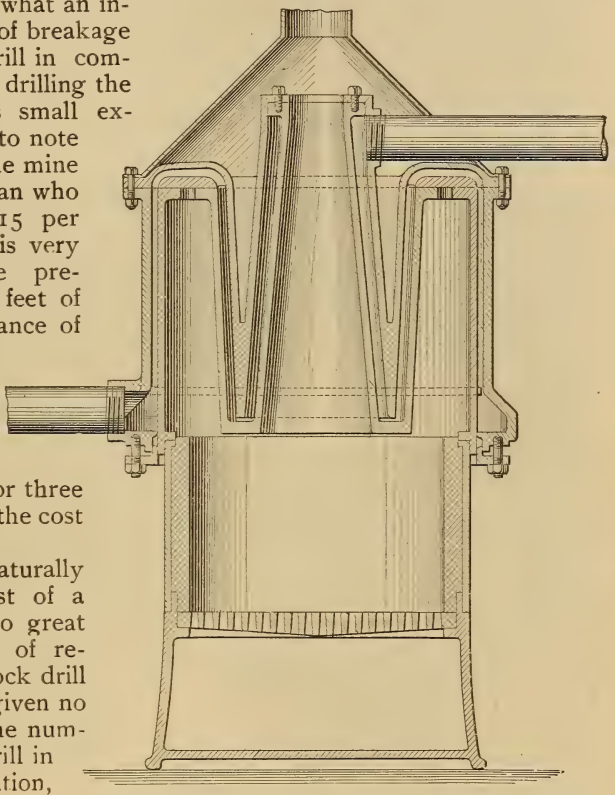
It will be seen from this what an insignificant item the matter of breakage and repairs is on a rock drill in comparison to the actual cost of drilling the holes. In contrast to this small expenditure it would be well to note that the amount saved to the mine by either a drill or a drill man who could drill, for example 15 per cent. more than another, is very considerable. Taking the previous figures, where 2280 feet of holes were drilled, an advance of 15 per cent. would mean a gain of 342 feet of holes, which, at a power and wages cost of 21 cents per foot, would be $71.82, so that at the end of two or three months a mine would save the cost of an extra drill.

From these facts it is naturally deduced that the first cost of a rock drill may be given no great consideration; the amount of repairs necessary to keep a rock drill in operation may also be given no great consideration; but the number of feet of holes it will drill in a month is the real consideration, and in a competition or comparison between different men or different drills the basis should be the cost per foot of holes drilled, this cost to be made up from the power cost of operating the machine plus the wages and the repairs.

The " Baby " drill, having a cylinder 2¼-inches in diameter, with a 4 or 5-inch stroke, is one which is at present demanding a great deal of attention from mine operators. It has been supposed that this drill had not sufficient power for general mine work on account of the vast difference in weight and strength of its various parts, as compared with the ordinary mine drill; but in certain California mines especially these little drills, made of steel, are drilling in hard metamorphic rock holes 8 feet deep at a less cost than with the larger machines, and one large mine has laid aside the larger drills entirely, excepting for shaft work.

The advantage of the " Baby " drill lies in the fact that it is a one-man drill, which cuts off at once one-half of the principal cost of operation. Its exceedingly light weight, viz., about 100 pounds, permits it being easily carried in stopes and in upraises, and its small size permits it to be used in close quarters. It takes less than one-half the air to run a " Baby " drill than one of the larger machines; consequently the air conduits are less expensive and easier put in place.

There seems to be very good reason



SECTIONAL VIEW OF AN AIR REHEATER MADE BY THE RAND DRILL COMPANY

why the smaller drills should fulfill many of the requirements of the larger machines, and in many places the selection of the size of the drill has been on a wrong basis. Sticks of powder about 1¼ inches in diameter are an average of the sizes used. It is, therefore, not necessary that the bottom of the drill hole should be any larger than 1¼ inches. Allowing five different lengths of drill to reach the bottom of a 5-foot hole, and allowing ⅛ inch clearance to each successive drill, it is evident that the hole need not be started larger than 1⅞ inches, and there is no need of wasting powder or employing a drill heavy enough to drill a larger hole.

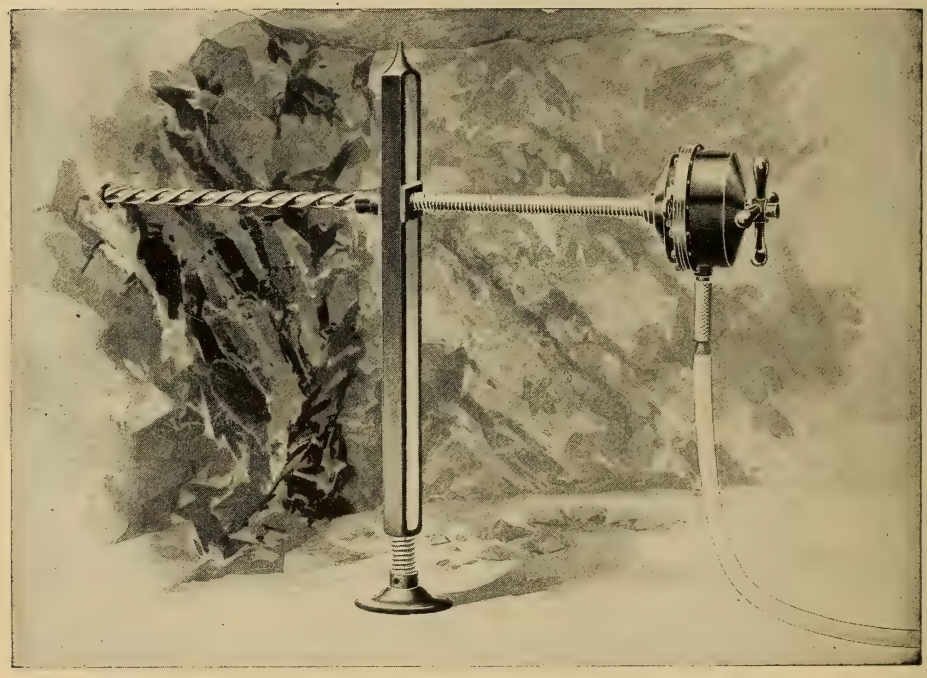
The larger the drilling machine, the larger the steel that has to be used with it to prevent it from buckling; and the larger the steel, the larger must be the diameter of the hole in starting, so that in many instances the ratios of the diameters of the drill cylinders to the diameter of the holes required for starting are such as to offset the advantages of the larger cylinders.

At a mine near Sonora, in California, the owner states that he is operating one "Baby" drill with a compressor driven by a gasoline engine. One man succeeds in drilling ten 4-foot holes in ten hours, at an expense of four gallons of gasoline, costing twelve and one-half cents per gallon. This is a remarkably cheap performance for drilling holes in hard rock.

COMPRESSED AIR FOR MINE HAULAGE

When the distances in a mine become great the cost of tramming ore and waste becomes quite an item. The length of time necessary for a round trip makes it difficult to handle the quantity, and man haulage gives way to a train of cars hauled by animals. Steam motors cannot be used, on account of their heat and smoke.

During the last ten years a great many mines have replaced animal haulage with compressed air motors, which lend themselves splendidly to the work desired. There are, in general, two sytems,—the low-pressure system, in



A COMPRESSED MOTOR DRIVING A BORING BAR IN COAL MINING

AN INGERSOLL DRILL IN THE GOLDEN HORSE-SHOE GOLD MINE IN WESTERN AUSTRALIA

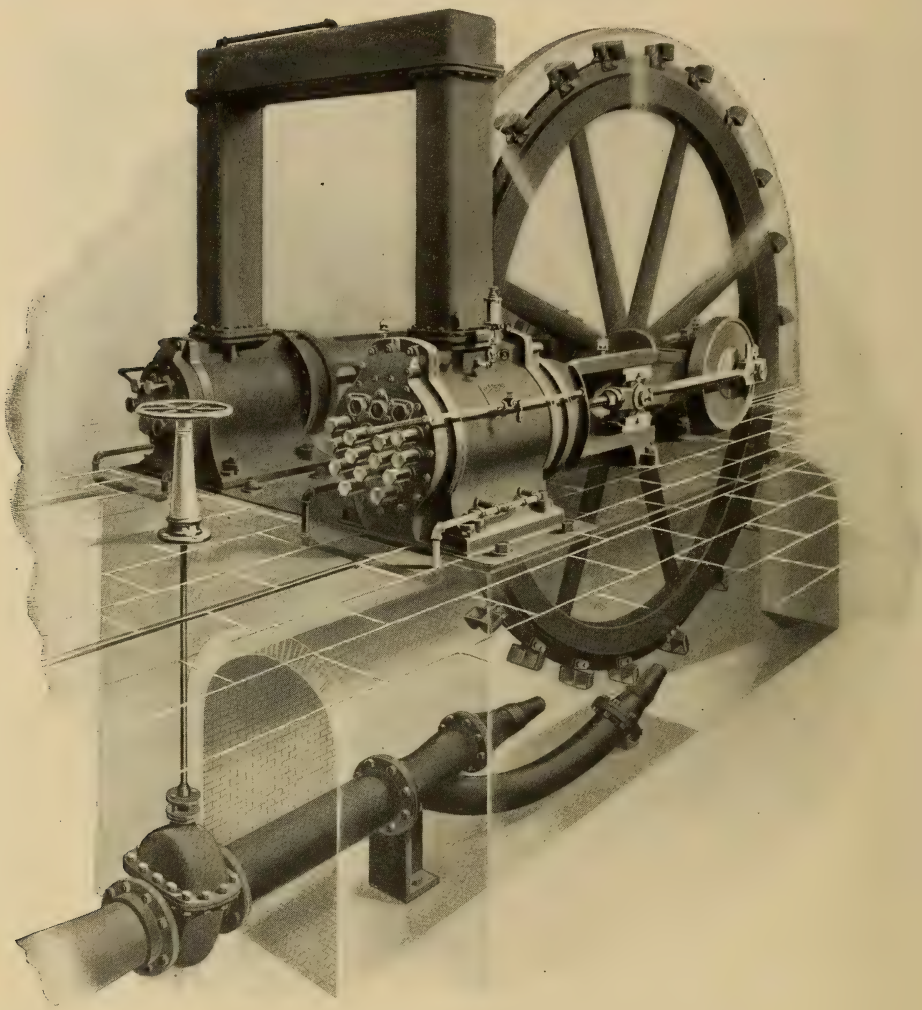
which air is compressed to five or six hundred pounds; and the high-pressure system, with air pressures of 2000 pounds and over. The former system can be used in large galleries or tunnels or drifts where the width is ample and the track is reasonably straight. This permits a large receiver on the motor, 30 to 40 inches in diameter and from 8 to 16 feet long, to be handled with ease. The high-pressure system is used where the drifts are narrow or the curves on a small radius, permitting only a small wheel-base on the motor. Large receivers are, therefore, impractical, and steel tubes must be used and charged with high-pressure air to get sufficient volume.

Compressed air may be used cold on either of these motors, or the air may be passed to small tanks of hot water supplied to the motor at the charging stations.

The air and hot water combination does almost double the work that cold air will do. These motors can carry sufficient air for any ordinary run desired and haul tremendous loads. Two miles and return, with fifteen or twenty loaded cars, is not an extraordinary effort, and from the general results obtained, the cost of haulage is from one-half to one-third of the cost of the animal power. The air escaping from the exhaust of the motor engines adds to the ventilating effect in the mine and the whole system harmonises thoroughly with the power outfit in the average mine.

During the year 1900 the writer was given the opportunity at the Morning Mine, at Mullan, Idaho, U. S. A., of installing upon their property a typical modern mining plant and one which contains most of the salient features that are considered important in compressed air engineering. A brief description of the plant, which, aside from being interesting from a compressed air standpoint, employs now the largest tangential water-wheel in the world and shows how three different heads of water can be harmonised on one compressor shaft, may not be inappropriate here.

The considerable cost of fuel to operate the steam-power compressors at the mine determined the management to utilise the water-power in the neighbour-



AN IMPULSE WHEEL MADE BY THE PELTON WATER WHEEL CO., SAN FRANCISCO, DRIVING A CROSS-COMPOUND AIR CYLINDER COMPRESSOR, BUILT BY THE RAND DRILL COMPANY

hood to drive a compressor large enough for future needs. Surveys of possible water-power were made long ago, and eventually a site was determined upon near Mullan which made it possible to utilise three water-powers; first, that of the Cœur d'Alene River, by building a dam and headgates just below the Morning mill and carrying the water in a flume to Grouse Gulch, giving 140 feet of pressure; second, by taking up the headwaters of Grouse Gulch and conducting them to a favourable point so as to obtain a fall of 1420 feet; third, by similarly taking up the waters of St. Joe and Rock creeks and obtaining a head of 1140 feet. The total capacity of these three sources would give a minimum of 1100 horse-power during the season of the lowest stage of water.

The river flume is built of planed lumber, and battened inside and covered. It is 5 feet wide by 4 feet high in the clear and about 8000 feet long, delivering into a steel pipe 42 inches in diameter and 400 feet long, reaching to the power house. The Grouse Gulch pipe line is 7350 feet long, containing 2000 feet of 9-inch and 5350 feet of 8-inch standard pipe. The Rock Creek

water-line consists of 2645 feet of 8-inch standard pipe. All of these lines are well anchored and completely buried.

The compressed air line consists of 9500 feet of 12½-inch inserted joint pipe, which reaches to what is known as Station No. 6. From there two 9-inch branches are made, one into the No. 6 tunnel, which, when completed, will be 10,200 feet long, and one branch of 9-inch pipe to No. 5, 11,700 feet long and into No. 5 tunnel 1500 feet, making a transmission of 22,700 feet to the present workings.

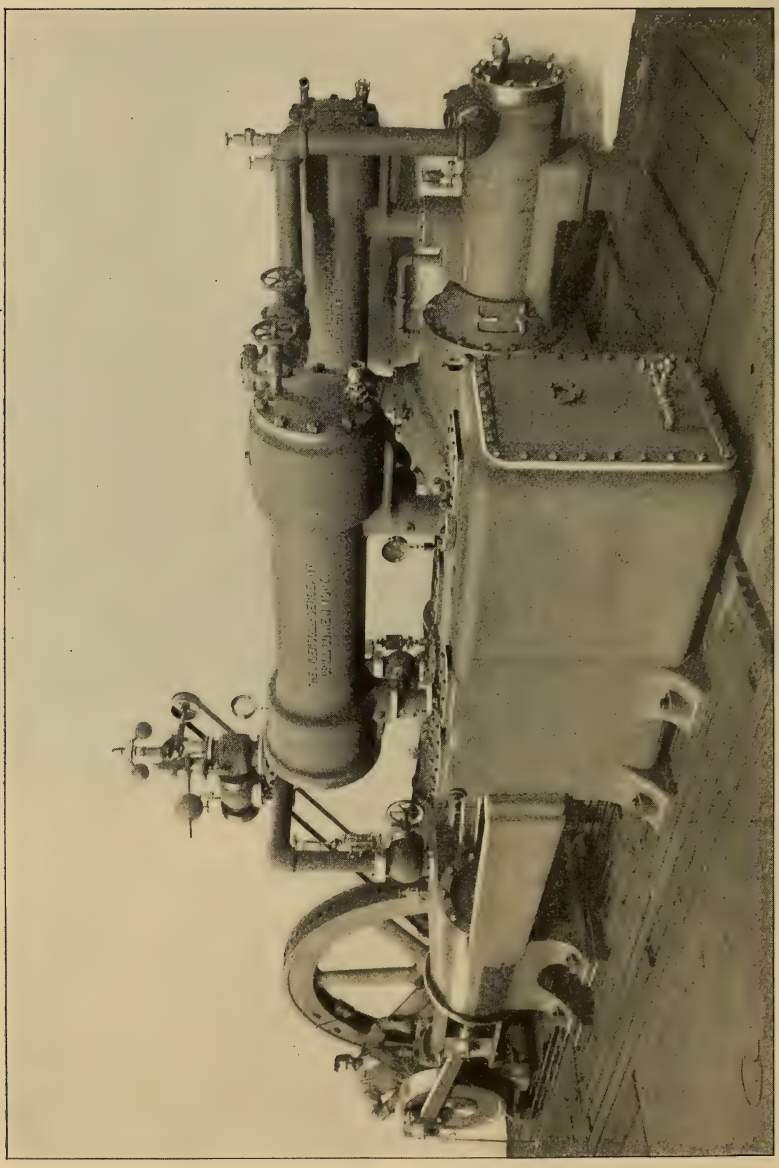
The compressor is designed to run 100 drills, and, owing to conditions relative to power, has offered a very interesting problem in compressor construction. On the main shaft of the compressor is mounted, as previously stated, the largest tangential water-wheel in the world, being about 33 feet in diameter.* The rim is made very heavy to serve as a fly-wheel, and the diameter is a compromise between the requirements of the two higher heads, taking eighty revolutions of the wheel as the standard number of turns. This wheel will give the tremendous rim speed of more than 8000 feet per minute, which has required special construction of the highest grade.

Two separate pipe lines convey the water to the nozzles at the periphery of the large wheel, and each nozzle is controlled by a suitable high-pressure gate valve and its by-pass, to prevent shock to the pipe line. The nozzles also have deflectors, so that the water streams may, in an emergency, be thrown from the wheel by the station operator. On the other side of the large wheel are two 11-foot Pelton wheels to receive the water from the Cœur d'Alene River, at a head of 140 feet, the total capacity of these two wheels being about 1200 H. P.

A COMPRESSED AIR MINE LOCOMOTIVE BUILT BY THE H. K. PORTER CO., PITTSBURG, PA.

The compressors are compound, compressing the air in the first stage to twenty-five pounds and delivering it into the mains at ninety pounds, the heat generated by the first compression being absorbed in a double set of inter-coolers placed in the tale-race of the low-pressure wheels. The compressor cylinders are, respectively, 32½ and 18 by 42 inches stroke, so that the piston speed of the compressor is 560 feet a minute, which is practically the limit of compressing speed. While this speed might not be disadvantageous to a single-stage compressor where the de-

*In addition to the illustrations of this plant on pages 346 and 348 of this article, it may be interesting to refer also to the elevation and plan given on pages 434 and 435 in the article on "Water Power in Mining," elsewhere in this issue.—THE EDITOR.



A FOUR-STAGE AIR COMPRESSOR, BUILT AND DESIGNED ESPECIALLY FOR LOCOMOTIVE MINE HAULAGE SERVICE BY THE INGERSOLL-SERGEANT DRILL CO., NEW YORK AND LONDON

livery occurs at or near the end of the stroke, in a compound compressor for the above pressures the delivery valve must open at about the centre of the stroke where the piston speed is 50 per cent. higher than the average. The delivery valves are thus compelled to open when the piston is moving at somewhat over 800 feet a minute. This presented a unique problem for valve construction, which has been solved in this instance by a very complete and satisfactory valve gear. All of the foundations are elaborate and expensive and are three separate stories in height. They are pierced by tunnels, and will be lighted so that any portion may be inspected at any time.

The intercooler is unique in character, and consists of a large number of 1¼-inch brass tubes, about 18 feet long, in a reservoir of water situated in the middle story of the foundations, flooded by backwater from the low-pressure wheels. Perforated floors under the intercoolers permit continual circulation, and are arranged to take away any sand which may be deposited.

The compressor is also fitted with an aftercooler, and underneath the cylinders and main frames a wide channel in the concrete is made, through which water continually flows to take away the immediate heat from the discharge valves, and to take away the discharge from the water circulations and also the oil and dust refuse. Each cylinder has two independent water circulations and each head has an independent water circulation. No expense has been spared to make this a thoroughly first-class and satisfactory installation.

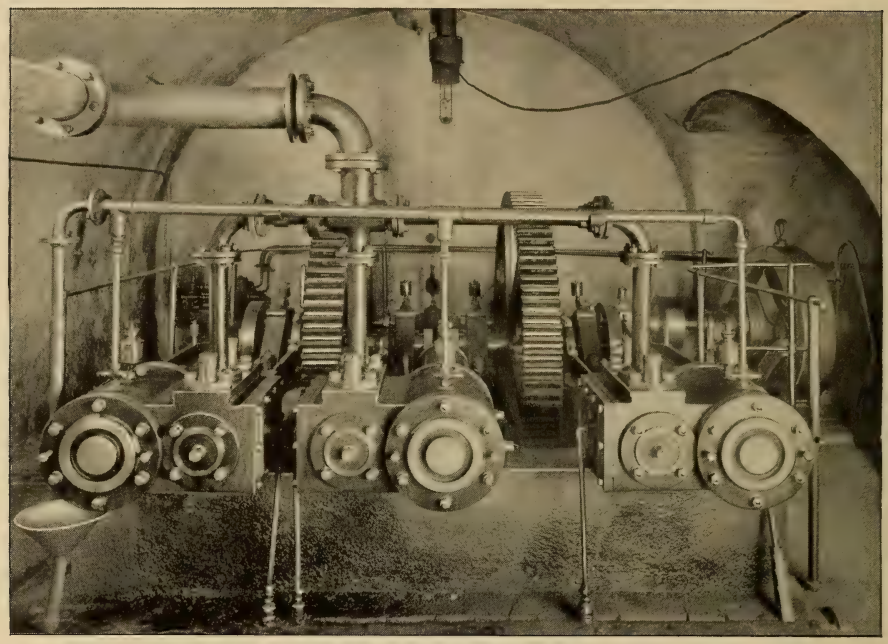
The plant has realised all expectations. The temperatures in the compressor are remarkably low, indicating efficient working. The pipe line is perfect, and was tested to 160 pounds water pressure before turning in the air. It is seldom that a compressor has an opportunity to pump into so large a reservoir, namely, 12,000 cubic feet at present, but which will be, later, about 17,000 cubic feet. At present the reservoir holds 100,000 cubic feet of free air at ninety pounds pressure, or about 10,000 stored horse-power, calculated on the basis of a reheated economical motor. It will be interesting to those who are contemplating compressed air transmissions to know that the loss in this four-mile transmission may be neglected. The Morning Mine closed down the old compressors and found, upon turning in the new line that it took about 2000 cubic feet of free air to do their present work. This amount passing through the pipes showed no appreciable loss on the gauges. It was not one pound at the most.

A RAND ROCK DRILL

COMPRESSED AIR FOR HOISTING

Compressed air is used for hoisting, both inside of the mine and on the surface. Either steam or compressed air is preferable to other media for hoisting, and the majority of hoists are built to use either one or the other medium, and the fact that they can be used in the same hoist proves an advantage in many places.

For underground work most of the hoists are small and are operated on



AN ELECTRICALLY DRIVEN AIR COMPRESSOR EQUIPPED BY THE ALLGEMEINE ELEKTRICITAETS GESELLSCHAFT, BERLIN

winzes. Except in particularly favourable places, these hoists are operated with cold air, and are, therefore, not economical, as far as power is concerned; but they are extremely useful.

A winze hoist should be backed up by a large receiver near by.

Compressed air timber hoists are an extremely useful appurtenance for underground work. They are very light, weighing five or six hundred pounds, have small reels and small geared engines, and are of powers ranging from 5 to 10 H. P. For hoisting timbers and drills into an uprise, or for hoisting timbers into stopes or around a mine generally, they are very useful. These hoists are also made on trucks so that they may be taken from one part of the mine to another very easily. All these underground hoists consume from 20 to 25 cubic feet of free air per horsepower of actual work done.

Surface hoists operated by compressed air are much in vogue, especially where the power is electrically transmitted to the mine. A portion of the electrical power is converted into compressed air to be used for the hoists. The most economical way to use this air is to so arrange the plant that the electrical power is practically constant and the compressor is just large enough to absorb this power. There must be large storage capacity, so that when the hoist is not in operation the power may be stored.

The hoist itself should be a compound, first-motion hoist to be a thoroughly up-to-date machine. A compound geared hoist is not quite so economical in air. The hoist cylinders should be jacketed. The air, after passing from the receivers, should go through a heater having two compartments, one for high-pressure and one for low-pressure air. In the first compartment the air is heated to about 400 degrees and passes around the jackets of the initial cylinder and finally into the cylinder itself, being exhausted from there back to the second compartment of the heater, where it is heated again to about 400 degrees, passes to the low-pressure cylinder of the hoist, and from there escapes to the atmos-

phere. A hoist of this character requires from 7 to 8 cubic feet of free air per horse-power, a vast difference as compared with the requirements of a cold air hoist. The cost of reheating is very small. The North Star Mine, at Grass Valley, Cal., using such a hoist, employs crude oil for heating purposes and consumes about a gallon an hour, which is insignificant in comparison to the power that this heating develops.

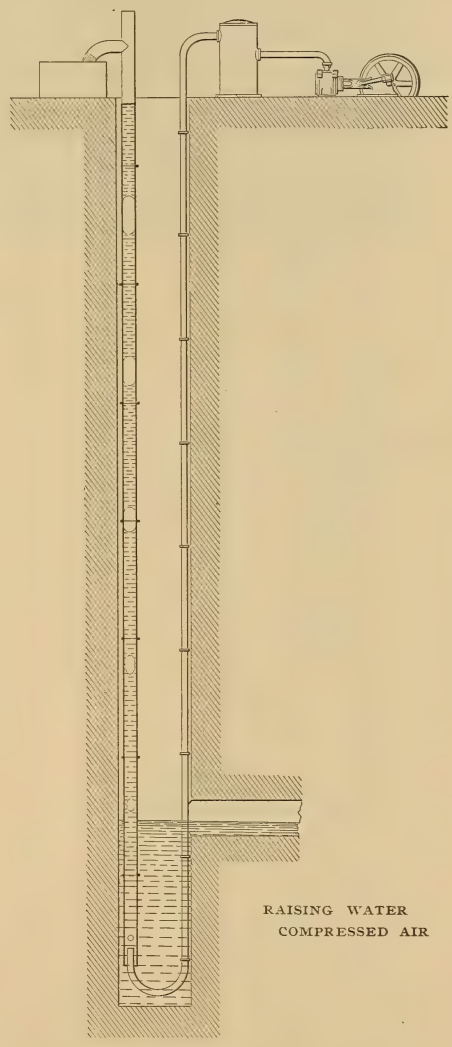
These compound, first-motion hoists are not expensive, even in first cost, and are extremely economical in operating. Large receiver capacity is an insurance against shut-down of the power plant, for unless the hoist itself gives way there will always be air enough on storage to bring the cage out of the mine, no matter what happens to the power plant.

COMPRESSED AIR FOR PUMPING

One of the most important uses of compressed air in a mine is for pumping, and within the limits of space the writer finds it difficult to properly consider the subject. Compressed air has been handicapped from the very beginning in the matter of pumping, because it has been used with stock pumps which have been designed in general for boiler feeding and tank purposes, and no particular regard has been paid to matters of cylinder proportions and appropriate pressures. Steam and compressed air are not similar enough in their phenomena to be used in the same motor.

The various rules and tables offered for calculating the amount of air required to lift water, without proper explanations, lead to the almost general conclusion that compressed air is a very expensive luxury. The percentage of efficiency credited to compressed air in the ordinary tables ranges from 15 to 30 per cent. No mention is made of possibilities beyond these numbers, and one is left but the one conclusion, that from 4 to 7 H. P. must be furnished to the compressor in order to produce a net yield of 1 H. P. in water pumped.

One hundred gallons per minute, lifted 200 feet, require about 5 theoretical H. P. Consulting the various tables at hand, it is found that the efficiencies range from 17 to 40 per cent., the pressures from 110 to 20 pounds, the quantities of free air from 225 to 130 cubic feet per minute, and the cylinder ratios from 1 to 5 to 1. It may also be noted that the pressures required for the same cylinder ratios vary

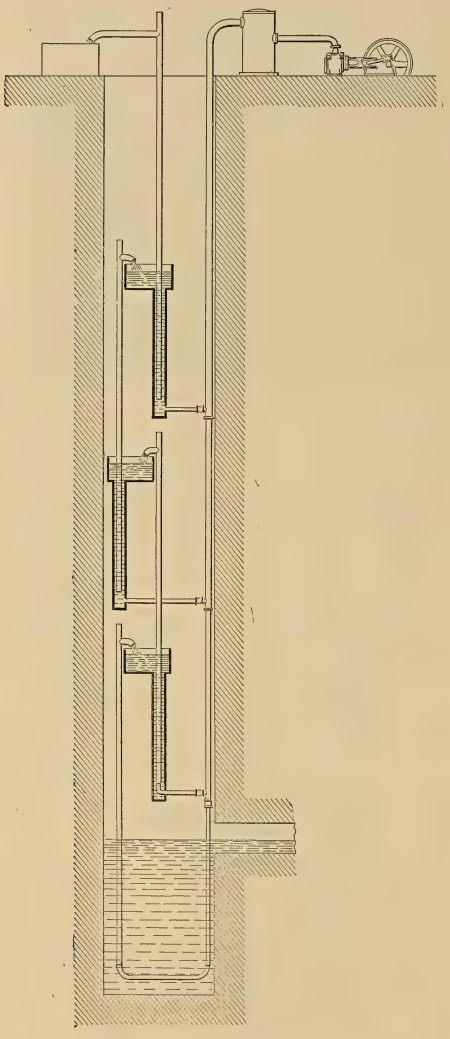


RAISING WATER
COMPRESSED AIR

150 per cent The pressures given are all receiver pressures, or pressures in the main air pipe, which fact is not mentioned, leaving one to draw the conclusion that no matter what the

pressure in the main is, it is only necessary to install a pump with large cylinder ratios and use low pressures.

The average pressures carried, in the main, correspond very nearly to the steam pressures formerly used for the same work, and ninety pounds gauge, independent of the altitude, seems to



A SERIES SYSTEM OF RAISING WATER BY COMPRESSED AIR

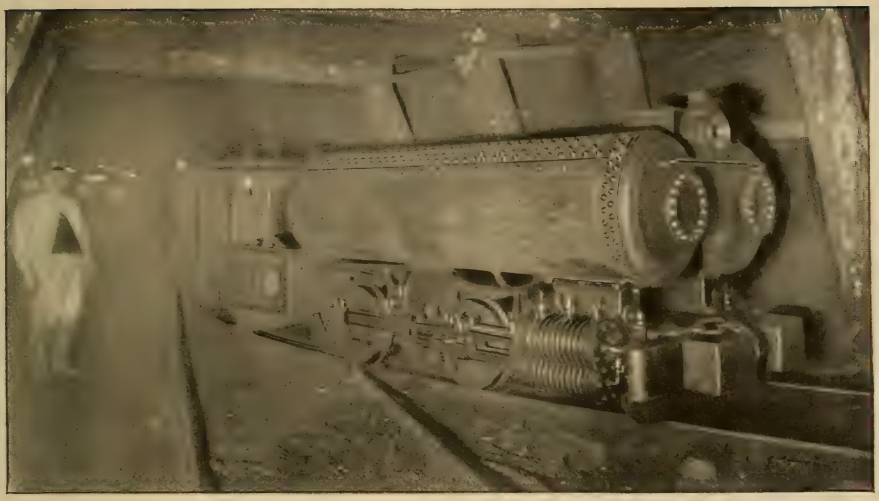
be the standard mining pressure. All tables and pumping data should be calculated from some such standard basis, with proper coefficients for variations for the standard pressure, and a table giving the proper cylinder ratios for the different heads, using standard pressures as a basis, would be more helpful to those who wish to consult tables for guidance.

There appear to be six general forms of compressed air pumps:—First, displacement pumps for full pressure only; second, displacement pumps using expansion; third, direct-acting pumps for full pressure only; fourth, direct-acting pumps using expansion; fifth, air lift pumps, simple and combined with displacement chambers; and sixth, pumps operated by independent motors.

In the first style of pump, illustrated by the Merrill type, two chambers are employed, submerged in the water, the compressed air being admitted directly to the chambers and displacing the water, the chambers acting alternately. With such a pump an efficiency of about 22 per cent. has been claimed, which is better than most ordinary direct-acting pumps will do with cold air. One can readily see, however, that this style of pump exhausts its chambers into the atmosphere at full pressure and all the expansive work contained in the air is lost. This system compounded, however, can be made very efficient.

In pumps of the second class, exemplified by the Harris system, the air, after displacing and raising the water as above, instead of being at once exhausted into the atmosphere is allowed to do work in expanding against the compressor piston, and thus, practically speaking, all its expansive energy is saved; but the manufacturers admit the losses in leakage and friction to be about 15 per cent. This is a very interesting and efficient system, and may be justly entitled to an efficiency of from 60 to 70 per cent. It should prove a very desirable system for mine station pumping.

In the third system we have a type of direct-acting pumps which are generally given a mechanical efficiency of 65 per cent. and an actual efficiency of from 15 to 22 per cent. They use the air at full pressure only. If a pump uses full pressure only, it is evident that the more full pressure a compressor diagram shows, the greater will be the



A COMPRESSED AIR MINE LOCOMOTIVE BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

efficiency of the system; the lower the air pressure, the less the compression work and the greater the proportion of full pressure work; consequently the lower the pressure, the more efficient the system. This really refers to the compressor and not to the pump, for the pump works the same whether it receives air at ten pounds pressure from the compressor, or whether it has been expanded from a receiver having a higher pressure, provided the temperatures are constant. If we look for the best efficiencies from the direct-acting pumps we must put in an independent compressed air system and carry low pressure.

The general conclusions in operating direct-acting pumps are as follows:—

First.—The lower air pressure in the main, with the cylinders designed properly, the greater the efficiency, reaching as high as 30 per cent.

Second.—The efficiency drops immediately if the air is expanded through the throttle into an air cylinder which requires less pressure than the main.

Third.—At standard mining pressure of ninety pounds the efficiency is about 17 per cent., with properly designed cylinders, and probably drops as low as 12½ in the pumps where just one turn of the valve is open.

Fourth.—Very little loss occurs in using pressures within 10 per cent. of the pressures in the main, which is ample to impart proper dynamic head to the pump. Compound compression will increase these efficiencies 15 per cent., and reheating will also increase the efficiencies in proportion to the ratios of the absolute temperatures.

Fifth.—Compound, direct-acting pumps are very little understood. The general idea has been that if the expansion of air produces such low pressures that it frequently freezes the simple pump, it would be an unwise proposition to try full expansion in compound pumps; conseqently compressed air users practically avoid multi-cylinder pumps.

To use compound pumps the air must be heated in some manner. This reheating can be done either with the water which is being pumped, or extraneous heating before the initial cylinder, or extraneous heating before the compound cylinder, or extraneous heating before both cylinders. By reversing the idea of the intercooler in compression and passing the air from the initial cylinder of a compound pump through a series of coils around which the water that is being pumped circulates, the air will take on very nearly

the temperature of the water, and it will be delivered to the second cylinder at practically the same temperature as the first, thus permitting a number of expansions to be used, and the efficiency of any ordinary compound pump may be made equal to from 37½ to 40 per cent. by this simple method of water reheating. In other words, almost double the water can be pumped for the same amount of air used in a simple pump.

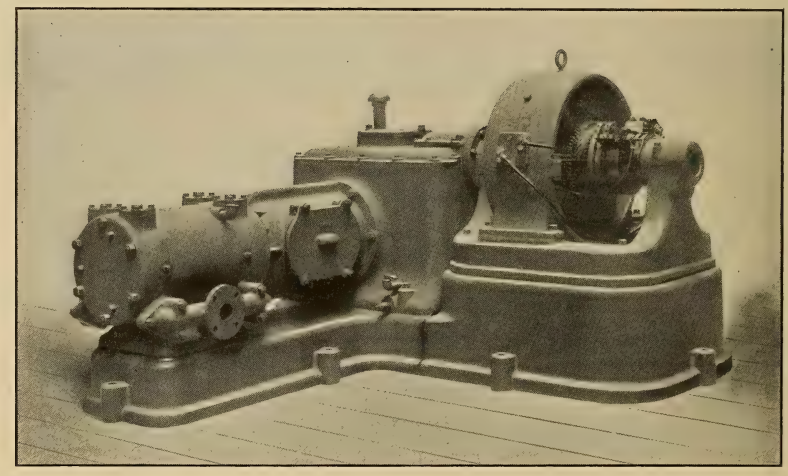
Where extraneous heating is used before the initial cylinder and between the two cylinders, the efficiency in compound pumps may be made to vary from 30 to 72 per cent., a vastly greater efficiency than is generally thought possible.

The combination of displacement and air-lift pump may be noted in the Wheeler pneumatic pump.

The Cummings, or the two-pipe system, is a very interesting one, consisting of compressing the air to a high pressure,—about 200 pounds,—and exhausting it back from the pump at 100 pounds. This may be made to give an efficiency of probably 50 per cent., and if reheated, possibly more.

Air-lift pumping, or the Pohle system, as it is called, is a simple system, which consists in reducing the specific gravity of water in the pipe by admixture of air, so that the head of water on the outside of the pipe will push it out. Extensive experiments have been made with it in America and in Germany, and it may be assumed that the efficiency may reach as high as, say, 50 and 60 per cent.

Motor-operated pumps consist of pumps belted or geared or directly connected to all kinds of engines. There is no doubt that with Corliss engines coupled directly to pumps, and properly reheated and compounded, the efficiency will reach somewhere about 75 per cent.



AN ELECTRICALLY DRIVEN AIR COMPRESSOR, BUILT BY THE CHRISTENSEN ENGINEERING CO., MILWAUKEE, WIS., U. S. A.

In conclusion, the efficiencies on the next page are suggested. The percentages given in the table there may be taken as fairly accurate in comparing the various kinds of pumps, and the relations between them will be properly expressed by these figures, even if the actual efficiencies, as determined by other observers, may be somewhat different.

In explanation of the following table, the writer would say that the figures are on the basis of a pressure in the air mains of ninety pounds gauge. By foot-gallons is meant the product of the

number of gallons pumped and the feet elevation that the water is pumped. This I find to be the most convenient and reliable way to designate the duty of pumps, and the foot-gallons designated are the work of one cubic foot of free air compressed to ninety pounds gauge pressure.

90 Lbs. Air Pressure on Main

Kind of Pump	Foot Gallons	Efficiency Simple Comp.	Efficiency Compound
1. Direct-acting simple	135	19	20
2. Direct-acting simple 300 reheated	180	24	28
3. Direct-acting compound, water reheated	232	32	375
4. Direct-acting compound, 1 cyl. heated 300	280	40	46
5. Direct-acting compound, 2 cyl. heated 300	326	46	53
6. Direct-acting triple cyl. heated 300	383	54	62
7. Direct-acting triple cylinder heated 400	444	63	72
8. Plain displacement	175	22	25
9. Wheeler displacement, 34 per cent for 34 lbs. pressure	---	--	--
10. Multiple displacement	320	40	46
11. Harris displacement	60 to 70 p. c.		
12. Merrill displacement	175	22	25
13. Cummings system	35 to 70 p. c.		
14. Compound motor pumps	50 to 80 p. c.		
15. Direct-acting triple water-heated	300	42	48
16. Pohle air lift, 30 to 60 per cent heads less than 300 feet	---	--	--

The second column shows the efficiency of the system with ordinary single-stage compressors and the third column with compound compressors.

No. 1 is the plain, direct-acting pump, like a plain boiler feed pump, and the table shows that one cubic foot of free air, compressed to ninety pounds gauge pressure, will perform 135 foot-gallons of work; that is to say, it will lift one gallon 135 feet, or ten gallons 13.5 feet, and so on.

No. 2 shows that the above pump will perform 180 foot-gallons of work if the air is heated to 300 degrees before entering the pump.

No. 3 shows that an ordinary direct-acting compound pump, using the water that is being pumped to heat the air on its way from the high to the low-pressure cylinder, will perform 232 foot-gallons of work, giving thus almost double the efficiency of No. 1, and requiring no fire heating,—simply a little more investment in the installation.

No. 4 is the same kind of pump as No. 3, heated by fire to 300 degrees between high and low-pressure cylinder instead of utilising the heat of the water. It is more economical, but the utility is not so high.

No. 5 is same pump as Nos. 3 and 4, but is fire-heated to 300 degrees before and after the high-pressure cylinder.

No. 6 is a triple-cylinder pump heated before and after the high pressure and after the intermediate to 300 degrees, giving 383 foot-gallons.

No. 7 is same pump heated to 400 degrees, giving 444 foot-gallons, showing that the same air as in No. 1, giving 19 per cent., can be made to give 63 per cent. properly manipulated.

No. 8 is a plain displacement tank, showing that it is more economical than an ordinary direct-acting pump.

No. 9, the Wheeler displacement pump, which is an ordinary tank displacement and an air lift combined, gives 34 per cent. efficiency.

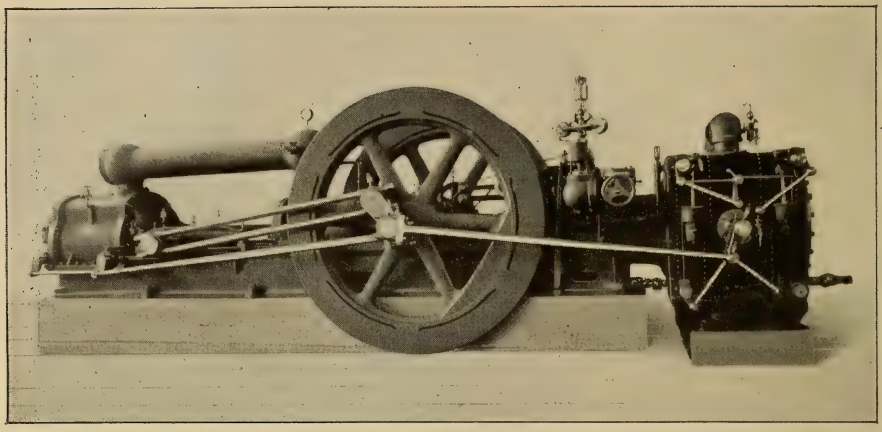
No. 10 is a multiple displacement proposition where the displacement tanks are arranged above one another at distances corresponding to the ratios of isothermal expansion, giving a calculated efficiency of 40 per cent.

No. 11, the Harris system, where, after displacement in a tank, the air is returned through the compressor to the other tank operating in harmony with the first, is the most economical way of handling water by compressed air that the writer has seen.

No. 12, the Merrill displacement system, is a plain displacement system of two tanks.

No. 13, the Cummings system, which is used in connection with direct-acting pumps, is a two-pipe or closed system, delivering air to the pump at about 200 pounds per square inch and exhausting back to the compressor at 100 pounds, the idea being to utilise, as far as possible, the full pressure part of the air card. The economy is quite high, from 35 to 70 per cent., depending on the pressures carried and the character of the pump.

No. 14, compound motor pumps,



AN AIR COMPRESSOR BUILT BY THE NORWALK IRON WORKS COMPANY, SOUTH NORWALK, CONNECTICUT, U. S. A.

refers to pumps driven by a compound air motor where heat is used before and after the high-pressure cylinder, and economies as high as 80 per cent. may be realised.

No. 15. Triple expansion, direct-acting pumps may be made to perform 300 foot-gallons of work, or 2.25 times as much as the same air will do with an ordinary direct-acting pump, by simply heating the air between the high and intermediate cylinders with the water being pumped, which has usually a 60-degree F. temperature.

No. 16 represents the air lift pump, which has an efficiency of from 25 to 60 per cent., depending upon the conditions.

COAL MINING IN INDIA

By Ernest Benedict, M. Inst. C. E.

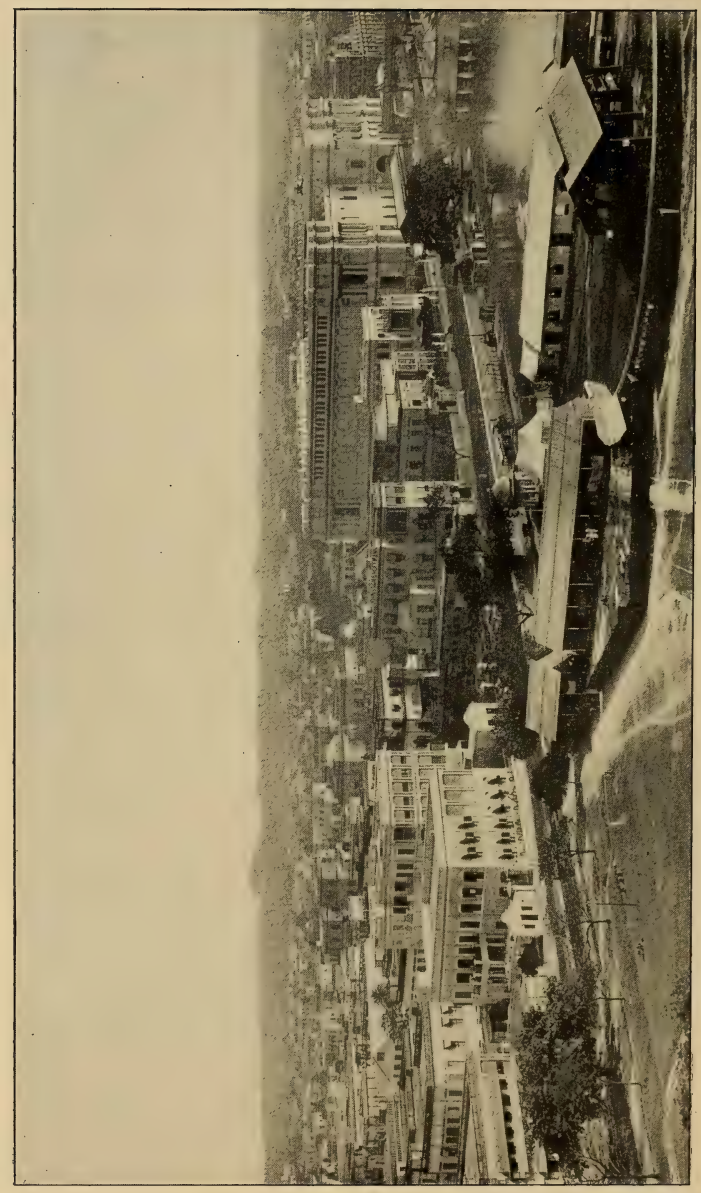
A BURMESE PAGODA

AT a meeting, not long ago, of the Indian Mining Association, Sir Charles Rivaz said truly that "mining is a new industry in India, undergoing a process of rapidly changing development: or, as put by Kumar Darshineswar Malia, 'Indian mines are still in their infant state.'" But the infant is a sturdy one, and threatens to outgrow its capabilities. The collieries, the wet nurses, who feed it, are sometimes injudicious by giving poor stuff, and its dry nurses, the government, the railways, the harbour authorities and the shippers, have not quite agreed upon the proper system of rearing the child, or on the best vehicles in which to administer its food. The ignorance of the man in the street, as regards Greater Britain in general, and India in particular, is positively stupendous. This article is intended to lift up one corner of this veil of ignorance and to show, in some measure, the actualities and possibilities of Indian coal as a valuable asset of the British Empire.

Professor Wyndham R. Dunstan, M. A., F. R. S., the enthusiastic director of the scientific department at the Imperial Institute, has been setting up a laboratory in that building which, he is determined, shall be second to none in its appliances for the radical investigation of the properties and peculiarities of Indian products. At the instance of the Government of India, he prepared a report some time ago in which he gave the results of the analyses of many samples of Indian coal sent to him by Dr. George Watt, the reporter on economic products to the Indian Government. In the majority of cases the samples differed greatly from those examined by Mr. F. R. Mallet in 1875-76, or by others at various times. This would show the advisability of having laboratories, at each important mining centre, in the hands of competent men, whose certificates would be guarantees to purchasers that they are getting what they want.

The Indian coal measures differ from those of Great Britain in that they do not belong to the carboniferous, but chiefly to the upper paleozoic and lower jurassic formations. The coal in Assam and in Burmah is principally cretaceous and tertiary, that in the peninsula itself belongs to the lower (so-called) Gondwana period. These differences account for many of the peculiarities in the composition and characteristics of Indian coal as compared with English and Welsh coal.

Coal is widely distributed in India, but many of the coal fields have not been fully explored, and only a small proportion of the total coal area is at present worked. When the Bengal-Nagpur Railway reaches the Jherriah coal fields in Bengal and the Assam-Bengal Railway taps the Makum district an enormous impetus will be given to the industry. Taking the mining areas in alphabetical order, this latter, the Assam district, heads the list. Up to the present time all the coal has been distributed by water. At first sight, this would appear to be an economical means of transport, but the erratic behaviour of the rivers in the Gangetic Delta counterbalances the advantages of this water carriage. The network



A VIEW OF CALCUTTA

of waterways in the delta is constantly changing its features, owing to the rapid raising of the beds and banks of rivers by the enormous deposits of silt with which they are laden. This lifting up of the water courses causes them, after a comparatively short time, to burst their banks and rush into some of their old, disused beds, which, in course of time, have become lower, and, therefore, afford an easier outlet than the more recent bed.

The Makum coal field is situated about 600 miles, as the crow flies, from the seaboard, in the heart of dense forest or jungle, among the Naga hills, in the North Lakhimpur district of Assam,

MINERS POSING FOR THE CAMERA

about sixty-two miles east of Dibrugarh, —a very shifting station on the Brahmaputra River, with which it is connected by a metre-gauge railway, built and owned by the Assam Railway and Trading Company, Ltd., who also own the collieries, some pottery works, a tea garden and a petroleum oil field at a place most appropriately named Digboi, and who have spent several millions sterling on these undertakings.

The natives of the country toil not, neither do they spin, for their wants are few and their clothing *nil*. The men are too proud to work and the women to be otherwise than chaste. In these attributes they resemble the Zulus in every way. As a favour or when they want to "make a bit," they will sometimes do a little jungle clearing, at which they are adepts. Labour, therefore, has to be imported. It consists of Santals, Moondas, Oorangs, Kols, Dhangurs and Bauries. To introduce the South Staffordshire method of getting coal in India it was found better to train young natives who had never seen a coal mine, under selected thick-coal miners, and there are now hundreds o natives working in the mines, good and careful workmen who, only a few years ago, were agriculturists, pure and simple, by heredity. Similarly, if an engine-driver, platelayer or other artisan is wanted, an agriculturist must be trained to the work. As a rule, they are willing to learn anything you wish to teach them; and, in time, make fairly good workmen. A high official of the company writes:—"As to the cheapening of the production, at any rate where we are, I am sorry to say we find the yearly tendency is quite the other way."

The field is thus described by one who knows it well:—After Bengal,

ONE OF THE COLLIERIES OF THE BENGAL COAL COMPANY

Assam is perhaps the district most richly gifted, but distance and difficulties of communication have hitherto kept it in the background. Its day, however, will surely come. The coal was first located in 1825 There is at Makum, in the side of the hill, an enormous seam of coal which is nearly pure carbon, a very little feathery ash being all that is left when it is burned. The coal is found in very thick beds and is worked by horizontal drifts in the hillside; it is used by ocean and river steamers, by railways and by tea factories. In one area alone, 5¼ miles long, averaging 600 yards in width, with a depth of coal of 100 feet, it is estimated that there lie 140,000,000 tons of some of the best steaming coal in the world. The output in 1900 was 216,736 tons.

In Baluchistan, coal is found chiefly near Khost and Quetta, most of it too friable to be of general use. The better quality is a good bituminous, coking coal; it burns well also in an open grate. The miners are nearly all Makranis, a few Pathans being also employed. The screened coal is used almost exclusively by the locomotives on the North-Western State Railway, and the small coal for brick burning; the available quantity of coal cannot yet be gauged, owing to the contorted state of the strata. The output in 1900 was 23,281 tons.

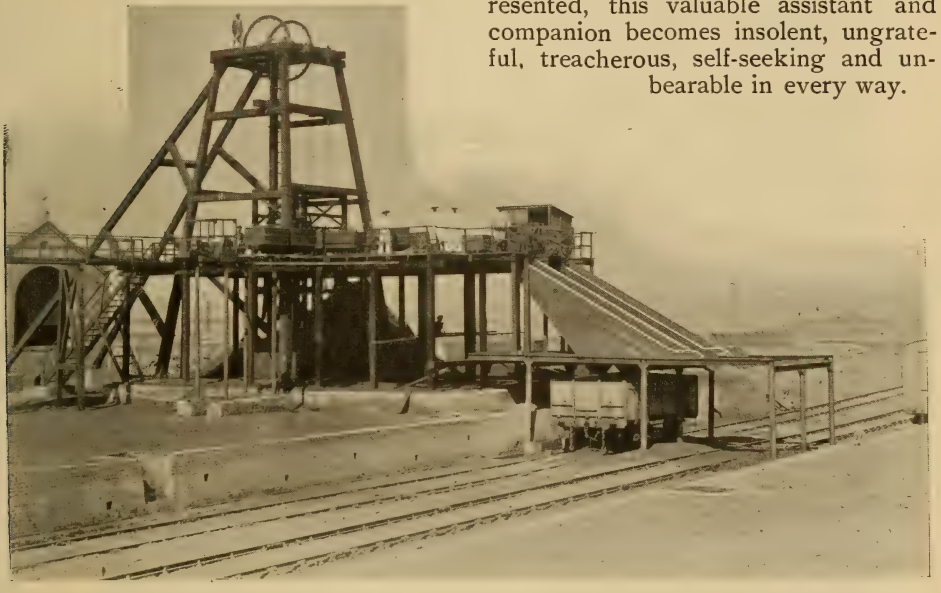
In Bengal there are collieries innumerable, the number worked varying with the demand and the price. The principal fields are:—

Name.	Distance from Calcutta in Miles	Area Square Miles	Estimated Contents Tons	
Karharbari	200 N. W.	8	136,000,000	Served by Railway
Raniganj	130 N. W.	500	14,000,000.000	do.
Barakar				
Jherriah	150 N. W.	200	465,000,000	do.
Bokaro	300 N. W	220	1,500,000,000	
Karanpura N		472	8,750,000,000	
do. S.			75,000,000	
Ramgarh		40	5,000,000	
Daltonganj	330 N. W.	200	11,000,000	
Total		1,640	24,942,000,000	

The best managed collieries are those of the East Indian Railway, who work them only for their own consumption, a little smithy coal, perhaps, being sold as a favour, to neighbouring railways; among them are also the mines of the Bengal Coal Company.

With regard to the former, one who has been largely responsible for their proper working, will be extensively quoted in the following notes. There is an essential difference between the miners of India and those of Europe. The latter are miners pure and simple, while the former are agriculturists, in the first place, and miners only in the second, so that, in the competition for labour which has risen with the great increase in the coal industry of Bengal, the allocation of plots of ground to the miners is a powerful inducement to them to settle on a colliery. Most of the mining work in Bengal is done by aboriginal tribes, Santals, Kols and

At a luncheon given by the French colonial engineers to the secretaries of the Indian and colonial sections at the Paris Exposition, in 1900, notes were compared, and men who had lived and worked in every part of the habitable globe came to the unanimous conclusion that so-called civilisation and education utterly spoiled the noble savage, who, by nature, is as courteous, as affectionate, as trustworthy, as unselfish and as useful in his way as a well-trained dog, when treated as one,—that is, as a friend whose powers and intelligence are limited. When varnished over with European notions of right and wrong, which, in real practice, are based on pure selfishness, soon discovered and resented, this valuable assistant and companion becomes insolent, ungrateful, treacherous, self-seeking and unbearable in every way.

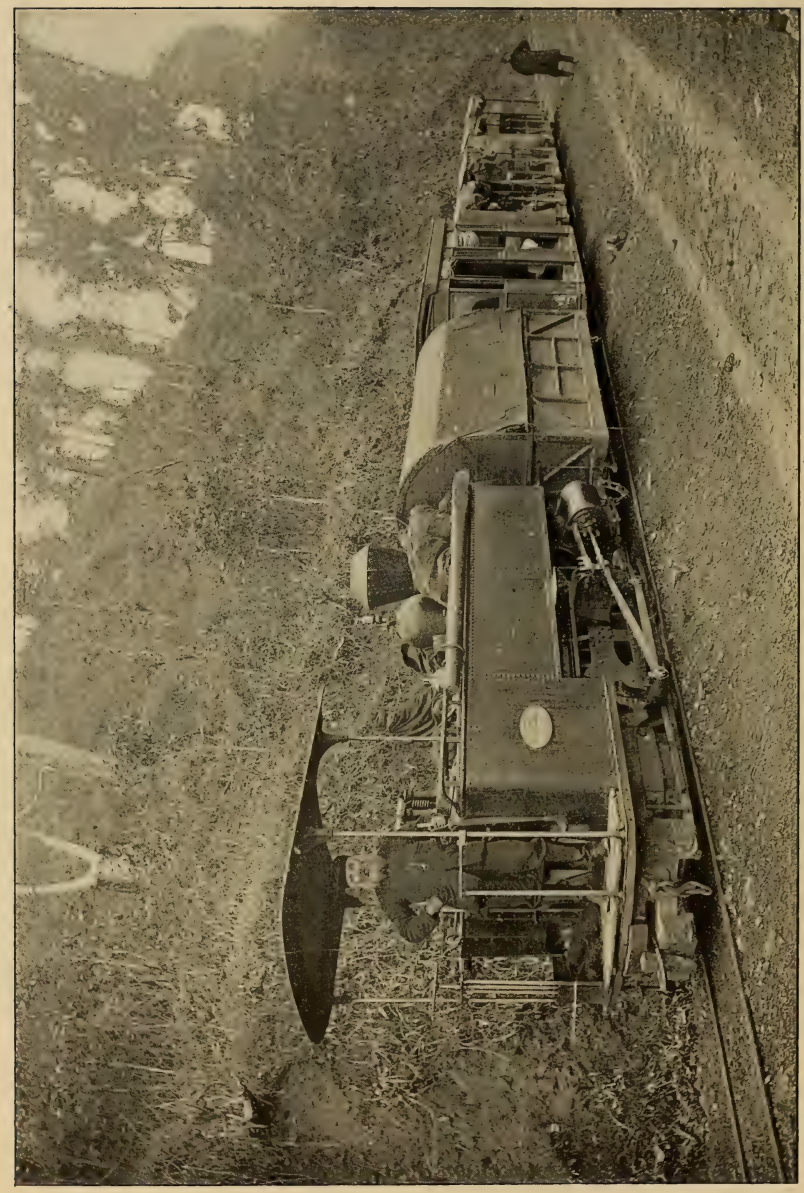


ANOTHER ONE OF THE BENGAL COMPANY'S PITS. BOTH ARE TYPICAL OF THE BEST PRACTICE IN INDIA

others, as already noted, the Hindus not having, so far, developed much taste for the industry. One very remarkable difference between the two races is that the aborigines have a habit, extraordinary in an Oriental, of speaking the truth; the average Oriental is a polite person and frames his answers, not with the slightest reference to the real facts, but to what he thinks the sahib would like to hear.

The whole family help at the work in the mine. The man gets the coal, and the women and children load it into the tubs and pick it. Many of them are well-to-do people, and it has been quite necessary to introduce into their leases a clause that they must put in so many days; otherwise the attendance at the mine would be very scanty in good seasons.

As Sir Thomas Wrightson very truly



ON THE NARROW-GAUGE ROAD TO DARJEELING

remarked in the discussion of a paper on "The Coal Problem; Its Relations to the Empire," by Lieutenant Carlyon W. Bellairs, before the Society of Arts, everyone in the coal trade knows very well that the cost of producing coal depends largely upon the working days that come into the fortnight. If at full work, they would be producing at the minimum price, and if at half work, they might be producing at a loss. The lecturer was still more emphatic.

"There are some demands made by the men," he said, "which are utterly inconsistent with the interests of the country. I may instance their objections to machinery, interference with the liberty of men to work to their full capacity, and attempts to assail the right of employers to accumulate reserve heaps of coal above ground. One result is that, while over 20 per cent. of the coal production of the United States is won by machine cutting, this modern method does not bring in as much as 2 per cent. of Great Britain's production. According to an American estimate the actual production per miner in the United States is 68 per cent. more than in Great Britain. Though the advantage of working on wider seams at less depth belongs to the United States, it is impossible not to feel that newer methods could reduce some of this balance against us. We must also endeavour to educate our working classes up to higher ideals and standards of living. If the miner is recruited from an ignorant class that cares only to earn thirty shillings a week, then, in times of good wages, the men will work only three days instead of four, and the result is a diminution in the output per man, tending to increase the scarcity."

FUEL GATHERERS

Labour is, in fact, the difficulty in the expansion of the coal trade in Bengal, as it is elsewhere. There are plenty of people, but only a certain number will touch coal mining, and those that do are philosophers. They say, "If I have a pice (a farthing) of fish and a pice of tobacco, why should I work?" The East Indian Railway has been experimenting with an electric coal-cutting plant; and, no doubt, it will, by degrees, make its way in Bengal. In this connection it is germane to quote an expert who was asked if Indian coal, judging

WHERE THE MINERS LIVE

from Professor Dunstan's analyses, could be profitably turned into producer gas. This is his reply:—

"There are quite a large number of kinds of coal in the report that will answer admirably in the gas producer, any of the non-coking or slightly coking, and, by preference, of course, those should be selected with the smallest percentage of ash. I notice the volatile matter is greater in most than in British coal, and the producers would have to be designed to deal with this greater volume of vapour, but this would constitute no difficulty." So much for producer gas, by which means most of the labour in and about the collieries might be done at even less cost than by coolies.

Coal mining in India is physically very different from coal mining in Europe. The very simplicity of it has been a hindrance to progress. There is no gas; the pits are all shallow; one of 300 feet is considered quite a deep pit; and many are entered by inclines, which the people much prefer, as they can stroll in and out at their pleasure. Consequently any man thinks he is good enough to be a manager, and the older pits resemble rabbit warrens more than anything else. Most people would consider an outcrop 90 feet thick as good as a gold mine, yet the genius who worked a quarry,—it cannot be called a pit,—where this occurred managed to tie the place up into a knot very soon by the simple device of putting the spoil ahead of him instead of behind. This want of capable managers is a crying evil which recent colliery legislation has intensified, and Kumar D. Malia is right in demanding mining institutions wherein to train them locally.

All the seams worked in Bengal are of a respectable, and many of them a great, thickness, 20 and 25 feet not being uncommon. In the railway collieries at Giridih or Karharbari, which produce about 400,000 tons per annum and are probably the best managed property in India, these thick seams are dealt with in the following manner:—An area is developed by driving out roads to the boundary, and the working is commenced backwards. Very large

pillars are left, about 40 yards square. When the time comes to work them out, they are divided into four; these, again, are undergone, and most of the coal is got out in this way before a fall takes place. The roof is tough and good, and, when a fall does occur, it is something to hear. Of course, that district of the mine is cleared when such an occurrence is expected.

A curious accident, caused by a fall, is on record. The mine was empty, but two men sat down in a cutting leading to an incline into the mine at some distance from the actual entrance. Nobody saw what took place, but their dead and battered bodies were picked up after the event; it is supposed that the violent gust of wind caused by the fall, issuing from the mouth of the incline, caught the two victims and dashed them violently against the stones and sides of the cutting.

A WHARF OF THE BENGAL COAL COMPANY

Bengal coal compares unfavourably with the Assam product in respect of ash. A good sample contains about 10 per cent. of ash; the worst is little better than stony refuse. Coal mining in Bengal dates from 1837, and the Bengal Coal Company was the pioneer in the industry, bringing its coal down by water to Calcutta, even after the railway was constructed. The bulk of it is raised from shafts, and is cut by native miners with wedges, hammers and picks. In the up-to-date mines an efficient system of underground tramways leads the coal tubs to the pit bottom.

The Equitable Coal Company are the sole introducers of coal-cutting machinery, but up to now it has not been a great success. It is in this direction, says an official of the Bengal Coal Company, namely, cheapening production by an increased output, that any improvement must be expected in the future, for the great difficulty is labour. Although India is a country teeming with humanity, the native is independent, thriftless and lazy by nature, the worst feature about him being that you cannot depend on him. Holidays throughout the year are his sole idea; he makes sufficient in one day to last him three or four, and immediately knocks off work. Most of the collieries are connected with the railway by sidings, and many of them have their own narrow-gauge tramway from pit mouth to railway loading wharf.

Bengal had an output of 4,954,956 tons in 1900, and its coal goes from Singapore, on the east, to Perim and

A NATIVE HOLIDAY DANCE

Jiboutil, on the west, including Rangoon, Madras, Bombay, Colombo, Aden and Perim, besides supplying most of the railways in Bengal and Northern India, and the great mill industries in Calcutta, Delhi, Cawnpore and the northwest generally.

The most important fields in Burmah are the Thingadaw, on the Irrawaddy River. The output is small, only 10,228 tons in 1900, but Mr. G. F. Reader, the coal specialist to the Geological Survey of India, gives great hopes of future developments. Mr. P. N. Datta, in his notes on the geology of the Mandalay-Kunlon Ferry Railway, writes that the matter of coal in the Southern Shau States has certainly not yet been finally disposed of in the negative, and relates the following anecdote:—"When Mr. Brown first visited this locality the coal was burning in one excavation, and a large concourse of people had assembled, declaring it was the fire of hell (Nga-ye-mi) escaping. Mr. Brown put out the fire with water, comforted them, and they dispersed to their homes."

The most important field in Central India, and the only one systematically worked, is that of Umaria, in Rewah, on the Bengal-Nagpur Railway, and thirty-four miles from its junction with the Great Indian Peninsula Railway, which lines take all its output. It covers three square miles, and is computed to contain 28,000,000 tons of coal. Mr. Reader speaks well of the prospect of the Sohagpur field, covering 1,600 square miles, close to Umaria. Two other fields cover 409 square miles, and the total output of them all in 1900 was 164,489 tons.

The mines in the Central Provinces produced 173,115 tons in 1900. The principal ones are:—Mohpani, on the Great Indian Peninsula, about 100 miles southwest of Jubbulpore, its junction with the East Indian Railway, and Warora, worked by the government, to which a branch line has been constructed from the former line, about forty miles from Nagpur, its junction with the Bengal Nagpur. Other mines are Shahpur and Pench, southeast of Itarsi, the junction of the former with the Indian Midland Railway, but not connected with it by rail; and Korba, Mand and Rangarh, covering over 1,000 square miles, and including several seams of

great thickness. They lie to the north of the Bengal Nagpur Railway.

In Southern India lie the Singareni coal fields, belonging to the Nizam and worked by the Hyderabad (Deccan) Company. The output in 1900 was 469,291 tons. They are on the Nizam's Railway, which now has direct connection, without break of gauge, with Bombay on the west, with Bezwada on the east, and from there with Madras and Calcutta. This field is also the nearest to the great iron ore deposits at Salem. The railways use almost all its present output. There are also five large coal fields, of which little is known, in the Godavery valley, between the mouth of the river and the Warora colliery, mentioned above.

There is an important colliery in the same valley and not far from the sea, in the Madras Presidency. It is called the Rajahzompalli, and has lately been put into working order, but no information regarding it is available.

The Dandot mines in the Punjab contain three seams, about 3 feet thick, and worked by the North-Western State Railway, the output having been 74,083 tons in 1900, with little chance of any increase. There are five other fields spread over the province which do not appear to have been fully explored.

The following figures will give a fair idea of the progress and changes in the coal industry of India:—

Year	Output. Tons	Used by Railways. Tons	Exports. Tons	Imports. Tons	Total Trade. Tons
1885.....	1,294,221	486,716	500	746,127	746,627
1890.....	2,168,521	654,829	26,336	760,306	786,642
1895.....	3,540,019	1,119,621	80,923	734,336	815,259
1900.....	6,095,428	1,855,610	541,445	83,236	624,681

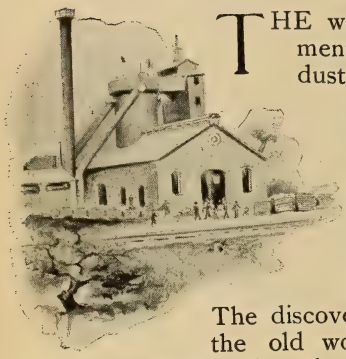
In 1900 about 750,000 tons of Bengal coal alone went by sea to Bombay, a ten days' run by steamer, beating the railway rates of delivery, in spite of the 200 miles lead to Calcutta: the difficulty in getting rolling stock: the charges at the two ports; the inadequate facilities for loading in Calcutta and consequent delays; and in spite of the sea-lead being nearly double the rail mileage, half a million tons were shipped to Colombo. The trade has quite outdistanced the appliances for dealing with it both on rail and in harbour; strenuous efforts are now being made to overcome these difficulties, and it is to be hoped that they will be successful.

It would have been impossible to have compiled these few notes without the cordial assistance of all interested in bringing a knowledge of the vast field for industrial enterprise which exists in connection with coal mining in India to the knowledge of the readers of CASSIER'S MAGAZINE.

THE ECONOMIC PRODUCTION OF IRON AND STEEL

INFLUENCE OF LABOUR–SAVING MACHINERY IN THE UNITED STATES

By Theodore W. Robinson, First Vice-President of the Illinois Steel Company, Chicago

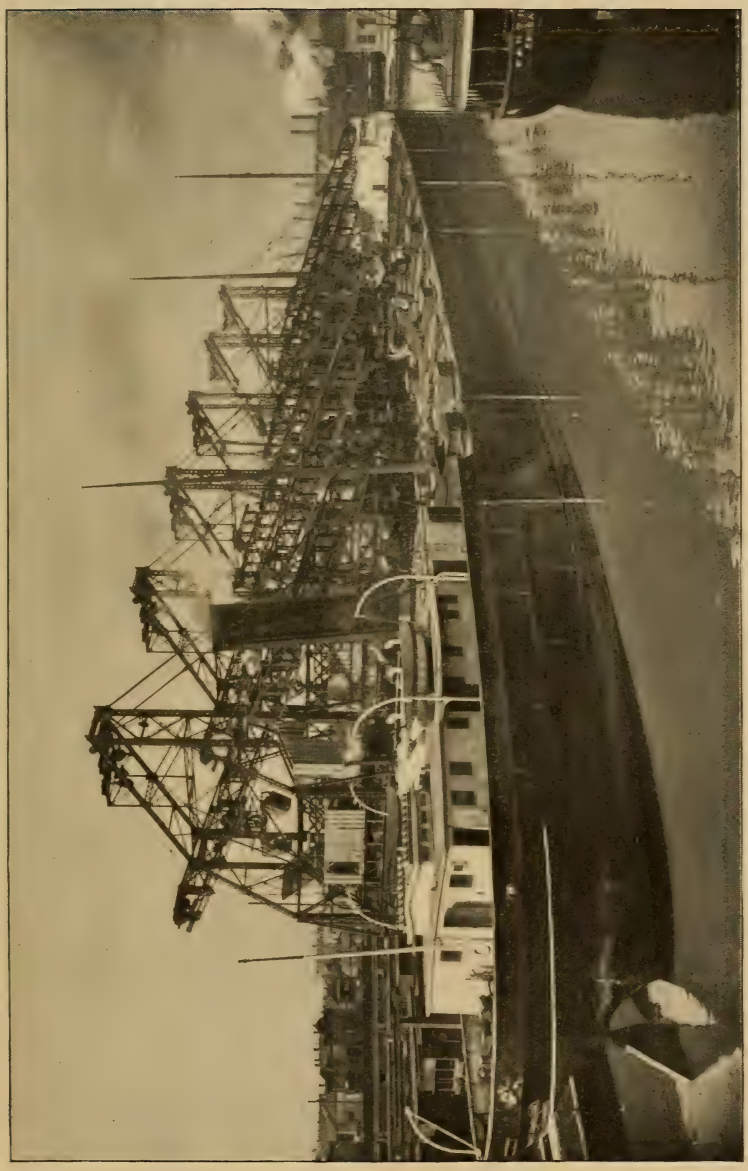


THE wonderful development of the steel industry during the past generation surpasses the flight of wildest fancy, and its story reads more like an Alladin tale than a chronicle of historic fact. The discoveries and work of the old world were fundamental, but it is to the subsequent genius of the new world that we are mainly indebted for the rapid progress that has succeeded. To trace the general evolution of the manufacture of iron and steel, even in a tentative way, is not the writer's purpose. It is in the growth and in some of the economies of American practice, as typical of the most advanced methods, that we are interested. The history is, chronologically, brief.

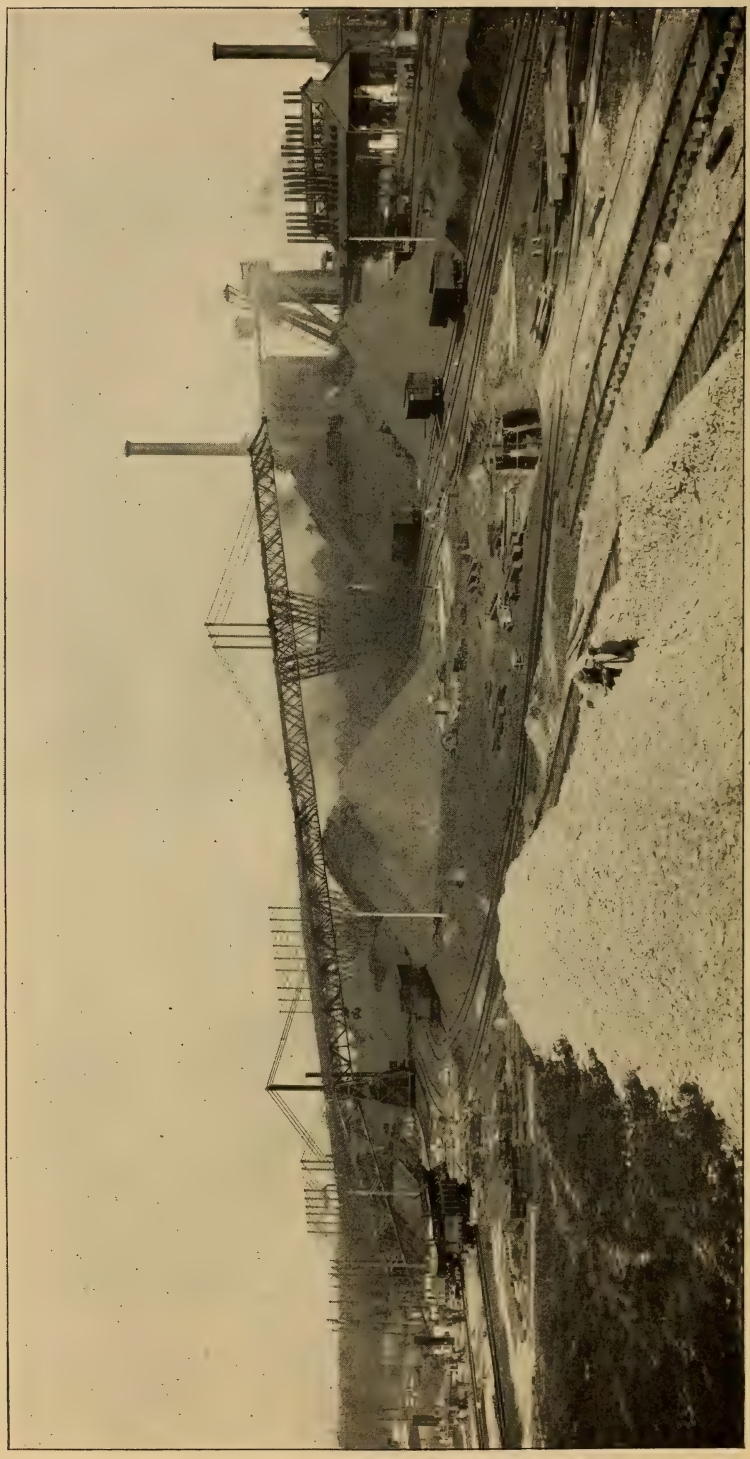
In 1870 the Menominee, Gogebic, Vermillion, and Mesaba ore ranges in the United States were unknown wildernesses; the waterways of the Great Lakes were little traversed, and the Bessemer and open-hearth processes were struggling for commercial recognition. The annual production of all grades of steel in the United States was under 70,000 tons, or an amount less than the monthly output of a modern Bessemer plant. It was the initial period of transition between rolled iron and steel, and iron rails were the principal product of the rolling industry. Thirty years have sufficed to increase the annual production of steel to 10,500,000 tons. The manufacture of iron rails has long been a thing of the past, and the price of steel rails has dropped from $166 to $28 per ton.

Such a transformation, broadly speaking, is a sequence to the economies that have come from the application of scientific methods to industrial pursuits. True, the incomparable resources of the United States have allowed an expansion not permitted to nations less favourably endowed. But natural resources, until developed, are intangible, and mineral wealth, while dormant, is of uncertain value. Irrespective of the opportunities naturally afforded, the direct cause of the rapid American advance is the increased efficiency of labour that has sprung from the introduction of new appliances and new methods at the mine, at the mill, and in transportation.

A NIGHT VIEW OF A BESSEMER CONVERTER BUILDING



UNLOADING AN ORE VESSEL WITH HOOVER & MASON MACHINES



THE BLAST FURNACE PLANT OF THE LORAIN STEEL COMPANY, LORAIN, OHIO

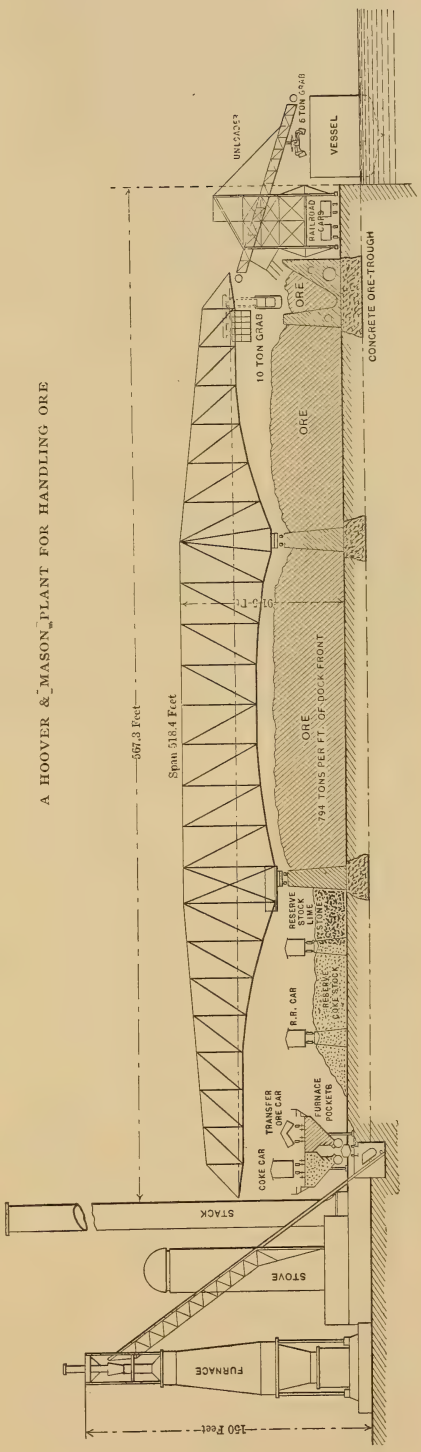
No industry has been more ready to recognise the merits of general discovery, or quicker to reap the benefits of new devices, than the manufacture of iron and steel, and a well-equipped plant is to-day the very embodiment of applied science. As we compare former types, it is patent that our present practice is essentially based on the underlying principles of a quarter of a century ago. The blast-furnace, the converter, the open-hearth furnace, and the rolling mill are still the agents of reduction and conversion. But here similarity ceases. Manual labour has been largely replaced by machinery; empiricism has given way to exact methods; tonnage has increased enormously, and products have been greatly diversified and cheapened.

It is not easy to concisely compare the old with the new, but for measuring the changes of the last three decades we can, perhaps, find no better yardstick than the steel rail. Its manufacture was not only the most important immediate result of Bessemer's discovery, but still affords the largest individual tonnage of any of the steel products.

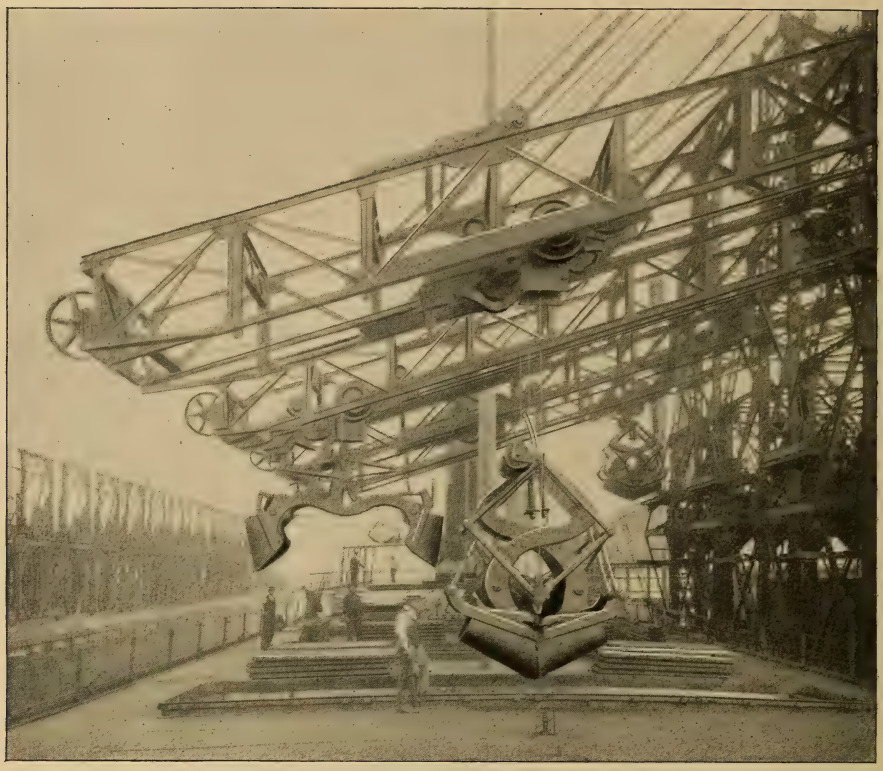
The metallurgical genesis of steel is at the blast-furnace, and, in studying its manufacture, we shall start with the ore, ready for delivery at the furnace yards. Through advance in technical knowledge, the introduction of the hot-blast stove, the development of the blowing engine, and the general use of labour-saving appliances, blast-furnace practice has been revolutionised. Where formerly 1200 tons a month were a large output for a furnace, and involved labour of the most arduous character, 19,000 tons of pig-iron have been recently produced in a like period from a single stack, and this in a comparatively automatic manner.

Such a tonnage involves the charging and disposal of 1800 tons of raw material every twenty four hours, and thus it is clear that the initial step in the rail's manufacture calls for quick and economic handling of large masses.

A very efficient design for the loading and unloading of ore is the Hoover & Mason machine, recently introduced on the Great Lakes. It is essentially a



A HOOVER & MASON PLANT FOR HANDLING ORE



A HOOVER & MASON ORE UNLOADING OUTFIT READY FOR WORK

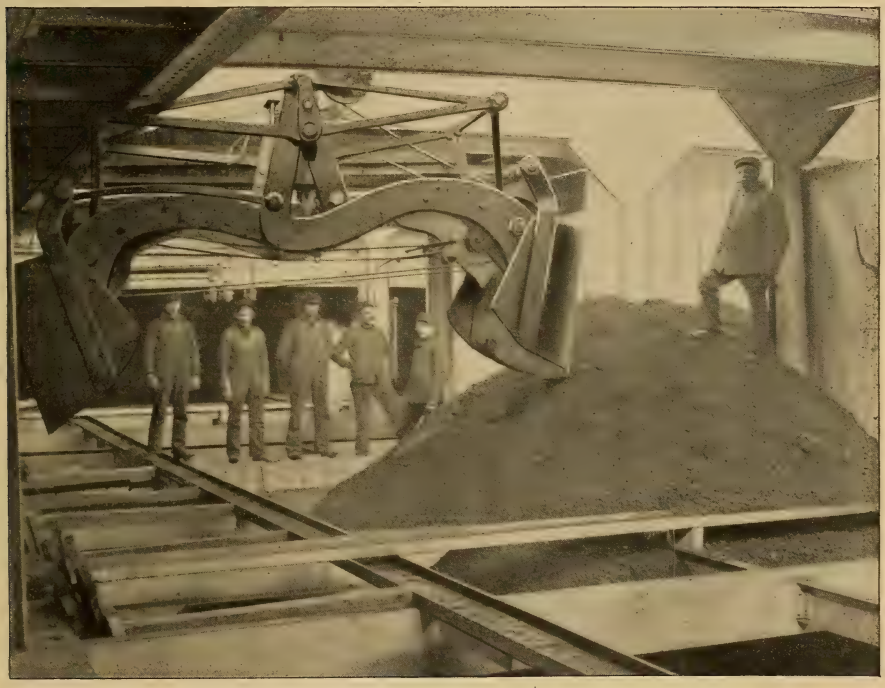
clever adaptation and control of the clamshell grab-bucket. As applied to the charging of ore boats, the machine is used in batteries of ten or more, one for each hatch of the vessel, the number depending upon the hatches that are to be worked simultaneously. When installed at a dock contiguous to ore storage and used in connection with ore-yard machinery, its employment is especially elastic and effective. Through combination with a concrete receiving trough, capable of holding several cargoes, the direct unloading of the ore from the boat is permitted either into cars for shipment, into stock piles, or into the furnace charging bins. The ore yards are spanned by immense cantilever trusses, having power of lateral locomotion and ability to operate along oblique lines. These are equipped with ten-ton grab-buckets, similar in design and operation to those on the unloading machines. In the shipping season they convey the ore from the receiving troughs to the stock pile or to the charging bins, and by their means the stored ore is transferred during the close of navigation.

With ordinary appliances it requires, under favourable conditions, ten to twelve hours to unload a vessel of ore. Six Hoover & Mason machines have handled over 1100 tons in an hour, and 256 tons have been taken from a single hatch in a like length of time. In illustration of what this means in increased labour efficiency, it is interesting to note that the relative effect of such a maximum tonnage, as compared with customary results at Lake ports, is that one man with one machine can do as much in an hour's time as fifty men with five of the ordinary machines where ore buckets are loaded by hand. With a battery of fifteen Hoover & Mason machines it is expected that vessels with a capacity of 7000 tons can be unloaded

easily and be free to return for another cargo within four or five hours after reaching the dock.

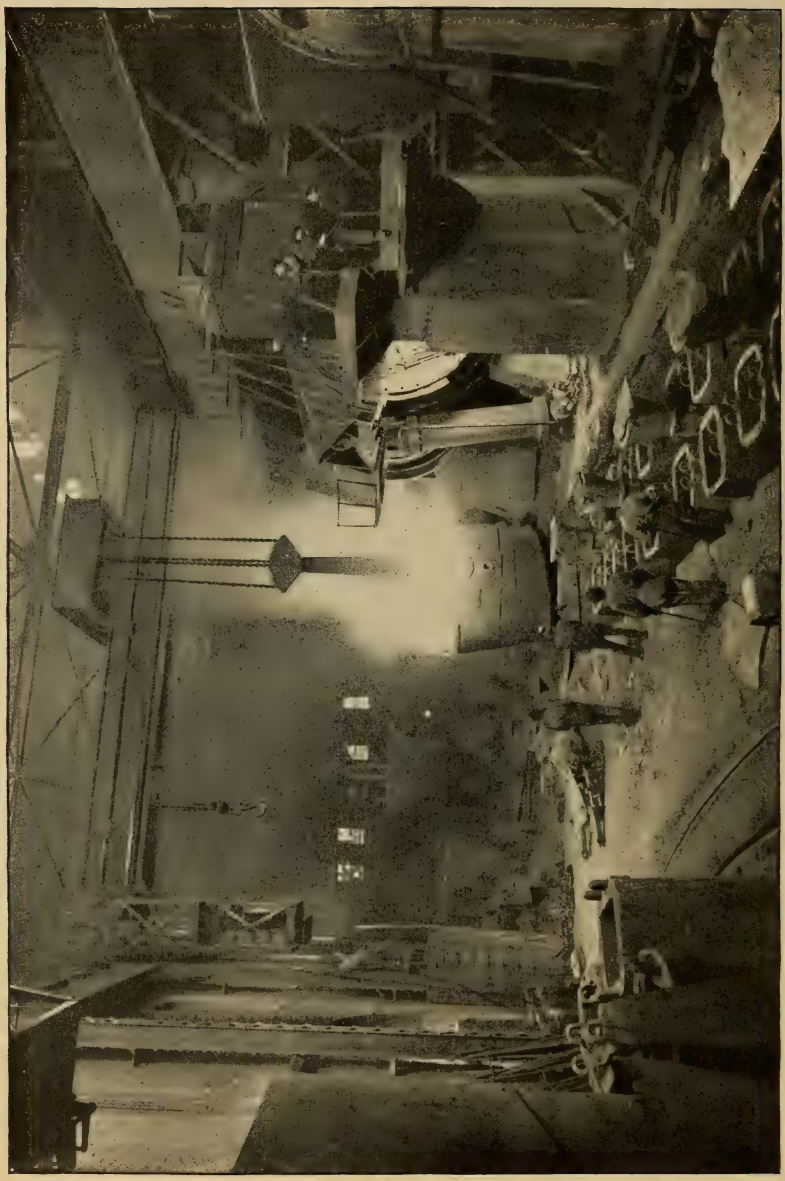
The use of charging bins and inclined skip hoists for the collection and charging of furnace material, though until lately not generally adopted, has, under recent modifications, become a prominent feature in blast-furnace design. Ore buggies, filled and hauled by hand and raised to the furnace top by cage hoists, while at the best uneconomical, sufficed for the requirements of a 200-ton blast-furnace. But to supply the demands of one of triple this capacity is a different proposition and one with which hand labour is entirely inadequate to cope. This need forced the evolution of the elevated charging bins and attendant electrically-propelled collecting car. With these as auxiliaries the modern skip hoist and automatic receiving and distributing furnace top permit of practically mechanical charging. At some of the best plants this work is done with an incredibly small number of men. At one recently completed, two men, one on the transfer bridge and the other on the receiving car, will pick up from the ore yard, collect, weigh, record, and deliver to the skip the immense amount of material required for a 600-ton furnace.

But the progress made in the economic handling of ore is by no means confined to the Lakes and to dock machinery. The cost of rail transportation and the expense of unloading has been largely reduced by the introduction of the 100,000-pound-capacity steel car and the use of the car unloading machine. At plants requiring the delivery of ore by rail the latter has proved a valuable adjunct, and the unique plan of discharging a car by picking it up bodily and reversing it has proved an effective method. Heavy railway equipment, with the assistance of the car unloader, has done much to reduce the differential formerly existing against inland locations.



ONE OF THE ORE GRAB BUCKETS IN THE HOLD OF A VESSEL

The development of the blast-furnace



A LADLE RECEIVING A CHARGE OF MOLTEN STEEL FROM A TILTING FURNACE AT THE SOUTH CHICAGO WORKS OF THE ILLINOIS STEEL COMPANY

has been contemporaneous with, and reactive in, its effects on the blowing engine. In the early seventies a good blowing engine was called upon to deliver about 7000 cubic feet of air per minute against a pressure of three to five pounds; 150 to 200 H. P. was developed, and a steam consumption of fifty to sixty pounds per H. P.-hour was considered good practice. Vertical and horizontal compound condensing engines are now built capable of developing 5000 H. P., with a steam consumption of sixteen pounds per H. P.-hour, and able to blow 45,000 cubic feet of air or more per minute against twenty-five pounds pressure. As measured by their performance, it would require six of the old machines to equal one of the new. The annual saving in fuel alone would be about $35,000 (£7000),—a sum roughly equivalent to the labour of fifty men working every day in the year.

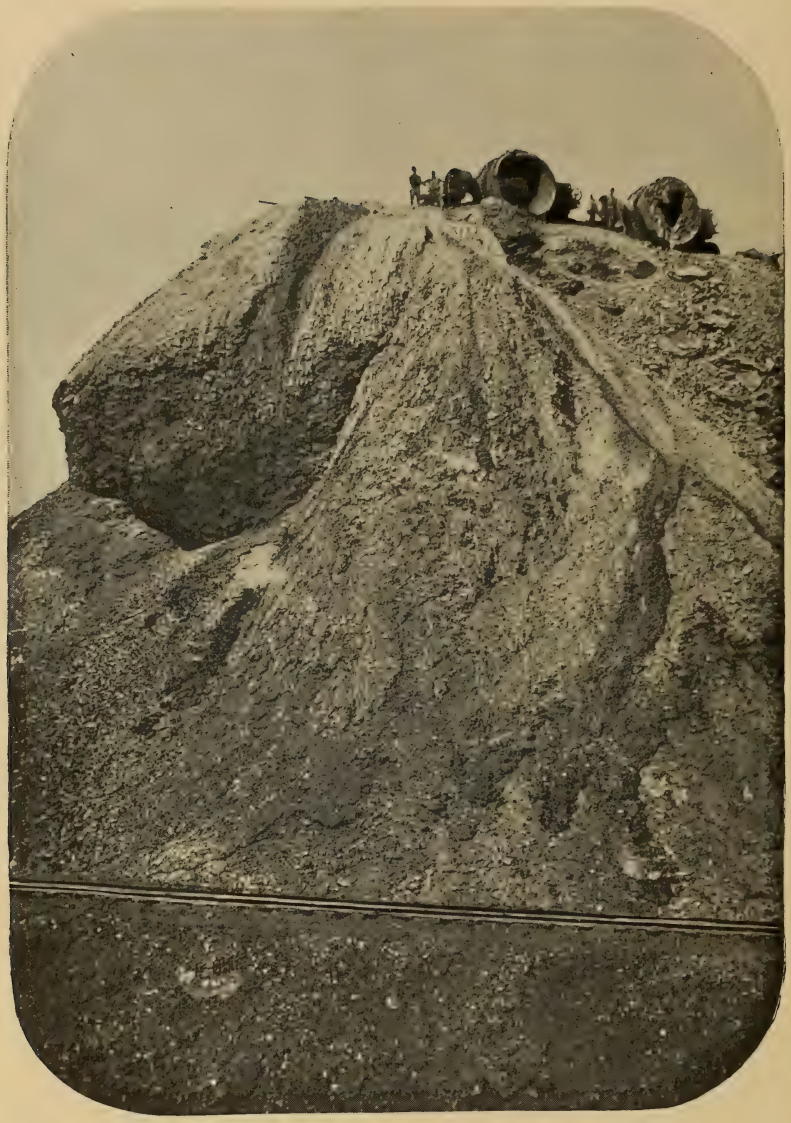
But ability to smelt large masses of material is but one-half of the problem, and such mechanical progress as has been obtained in the charging and in the operation of the blast-furnace would have been largely abortive had not the introduction of the cinder ladle and hot metal car allowed a correspondingly expeditious movement of the molten pig-iron and of the liquid slag. Their innovation sounded the knell of the iron carrier and cinder snapper, and their occupations have practically passed.

A blast-furnace makes, volume for volume, approximately 50 per cent. more slag than it does pig-iron, and it is clear that the problem of cheaply disposing of this waste material is an important one. Acres of sunken land have been filled; small mountains of such *debris* have accumulated, and the ladle car, by its assistance in handling this refuse, has played no small part in raising the productiveness of a modern blast-furnace to sixteen times that of its prototype of three decades ago. Furnaces of the latest design are conspicuous by the absence of the cast-houses that formerly provided the means of casting iron into sand. The ladle car into which the molten iron is now run direct has supplanted that part of the process, which was ever restrictive and expensive. In studying the changes of the past thirty years on the efficiency of blast furnace labour, it is found that the return of the present economic blast-furnace workman averages seven or eight times that of his predecessor.

There are thousands directly engaged in the smelting of pig-iron in the United States. When it is considered that for each individual now so employed the labour of seven or eight men has been saved and converted into other productive channels, the import of mechanical and metallurgical advance in this line of work is apparent.

Attention now turns to the converting mill,—the next natural division of the various steps in the rail's fabrication. From the blast furnace there are two ordinary avenues of approach,—one through the mixer, the other through the pig-casting machine. Their use depends upon whether the metal which was left still molten in the ladle car is to be employed direct, without cooling, for conversion into steel, or whether resort is to be had to the old plan of smelting in cupola furnaces. The latter, as an adjunct to the Bessemer converter, has become practically obsolete, and, in the best plants, is used only in caring for Sunday and such iron as the converter cannot promptly receive. The mixer, which, in form and effect, is nothing more than a tilting, refractory-lined reservoir, marked the downfall of the remelting cupola and opened a new epoch in the manufacture of steel. Into it the molten metal is poured from the ladle car, there to become amalgamated and take on the composite character of 200 tons or more of preceding metal. The advantages are obvious. Initial heat is conserved and the cost of remelting is saved; iron of varying composition from different blast-furnaces is mixed, and irregularity in conversion, due to inequality in character of metal, is minimised.

When the exigencies of the case do not permit the employment of the mixer the pig-casting machine provides mechanical means for casting the product



A CINDER BANK AT LEBANON, PA.

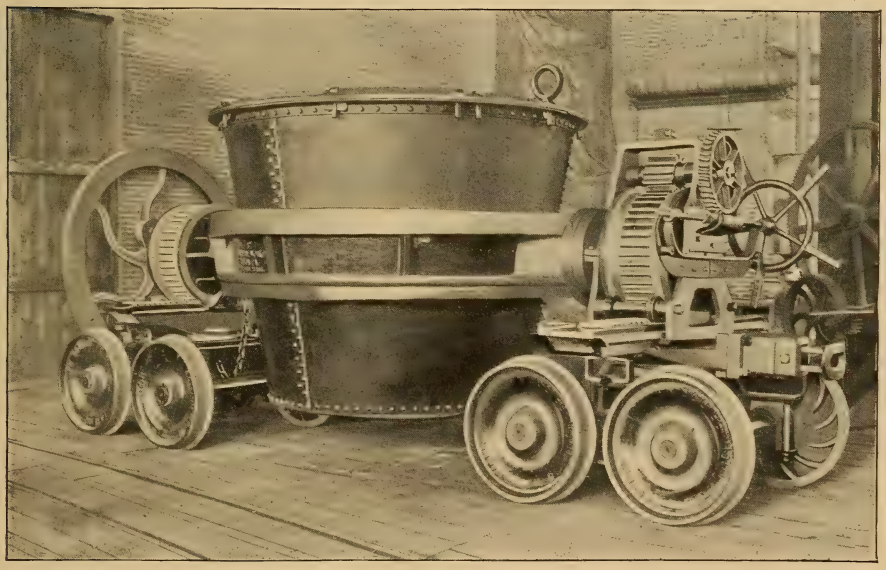
of the blast-furnaces into pigs. While there are various forms of this machine extant, each with its individual advantages and peculiarities of construction, all perform the same office. Small, slowly moving iron moulds actuated by attachment either to an endless chain or otherwise, are filled with metal from the ladle car. On their forward movement the pigs thus formed are cooled by contact with water and are automatically dumped into cars, ready for transfer to the melting furnace. From its various economies the pig-casting machine has found general favour and has been extensively introduced.

The refining of the iron at the converter by the combustion of its own impurities is dramatically picturesque, and in comparison with the operation of

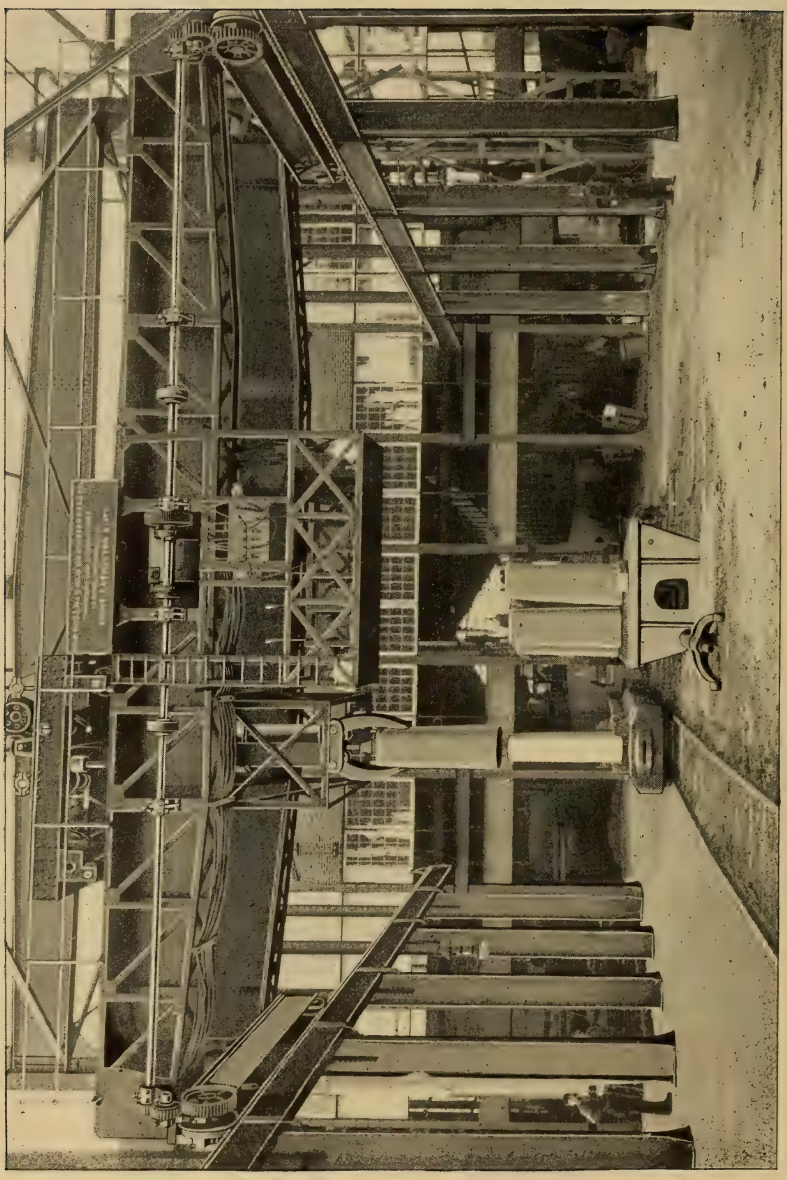
twenty-five years ago presents a most striking example of the effectiveness of modern methods. At that time 200 tons a day represented a large output. To-day a modern mill produces as much in twelve hours' time as the old one formerly turned out in a week. The increase in the number and size of the vessels, greater blowing power, and intelligent application of hydraulics and electricity all have had their share in this metamorphosis. The casting pit has given way to the pouring of steel direct upon cars, and the man with the sledge, struggling with the ingot that would resist parting with its mould-embrace, has been supplanted by vertical hydraulic rams that strip the ingot and remove the moulds with ease and dispatch. These are some of the elements that account for the increase in production from 5000 tons to 85,000 tons a month and have caused the average efficiency of converting mill labour to become six times as great as it was under the old *régime*. As measured by the average results, one man now does as much work in the conversion of steel as six men did a short generation ago.

In passing, tribute should be paid to the researches that have made the chemical and physical laboratories the monitors of the rail's development. Without their guidance much that has been accomplished would have been impossible of attainment. At the very threshold of steel-making the reagent plays an all-important part in the selection and manipulation of the raw materials. Their character and action are no longer subject to individual judgment and bias, but are amenable to definite determination and control. Failures of finished product, formerly mysterious and unanticipated, are now, through analysis and the testing machine, largely understood and guarded against. The laws of chemistry and physics, in their practical application, play an unostentatious, but vital, part in the manufacture of steel.

The metallurgical evolution of the rail may be considered as essentially complete when it leaves the converting mill. The subsequent steps are either preparatory to or of actual mechanical treatment. Separated from the moulds that formed them, the upright ingots, still glowing with their initial heat, are carried upright, on iron cars, to the vertical heating pits. There they are



LIQUID CINDER CAR MADE BY THE WEIMER MACHINE WORKS COMPANY, LEBANON, PA., U. S. A.

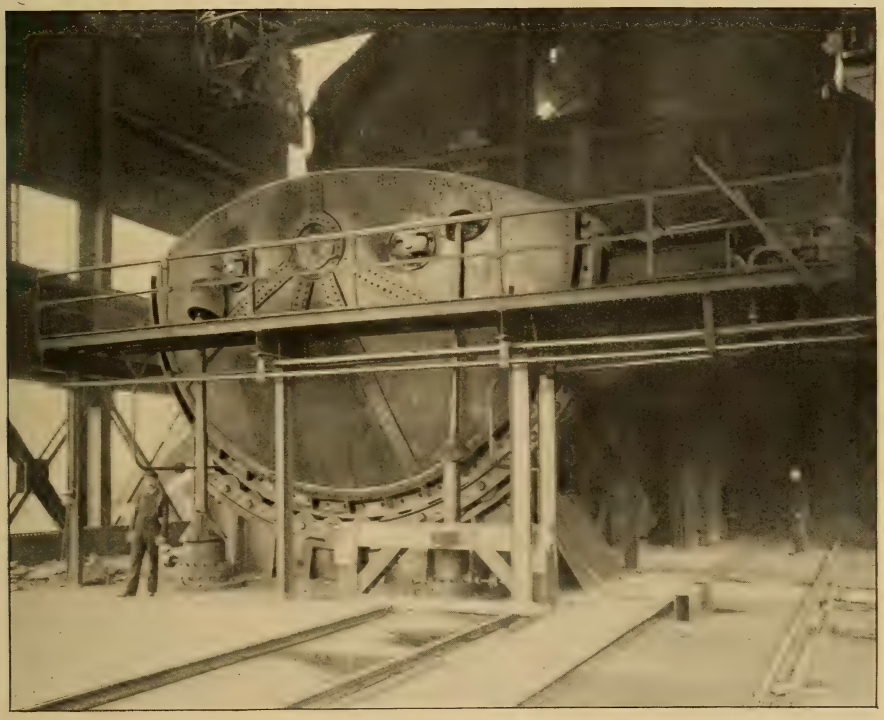


AN ELECTRIC INGOT STRIPPER AT THE PITTSBURGH WORKS OF THE AMERICAN STEEL AND WIRE COMPANY. THE MOULDS CAN BE LIFTED FROM THE INGOTS AT ANY PLACE ALONG THE RUNWAY BENEATH THE BRIDGE SPAN AND DEPOSITED WHEREVER CONVENIENT. BUILT BY THE WELLMAN-SEAVER-MORGAN ENGINEERING CO., CLEVELAND, OHIO

tempered and await their turn for their journey through the rolls.

As we look back upon the horizontal ingot furnaces formerly in vogue and recall the clumsy and expensive method of charging and drawing with peel and tongs, it is apparent that the art of heating steel has kept abreast of the times. Its progress, since the invention of the regenerative heating furnace, has been one of mechanical auxiliaries and minor modifications rather than of fundamental changes. The handling of heavy pieces of hot metal in and out of furnaces, whether in the shape of ingots, billets or slabs, involves many difficulties. Strong and heavy machinery is required to withstand the wear and tear imposed, but expedition, with delicacy of movement and accuracy of control, is necessary.

In solving the problem, modern charging and drawing machinery has become an essential link between the converting and the rolling mills. Not only is it an important factor in commanding large tonnages, but it has proved one of the most efficient of labour-saving devices. Various kinds are used, depending upon the character of the metal to be heated and upon the individual preference of the engineer. Electricity and hydraulics, separated or combined, are the usual actuating forces. In heating rail-steel, the pit furnace is ordinarily employed in order to minimise the pernicious effects of piping and the segregation of impurities. This it tends to do by maintaining the solidifying ingots in a vertical position.



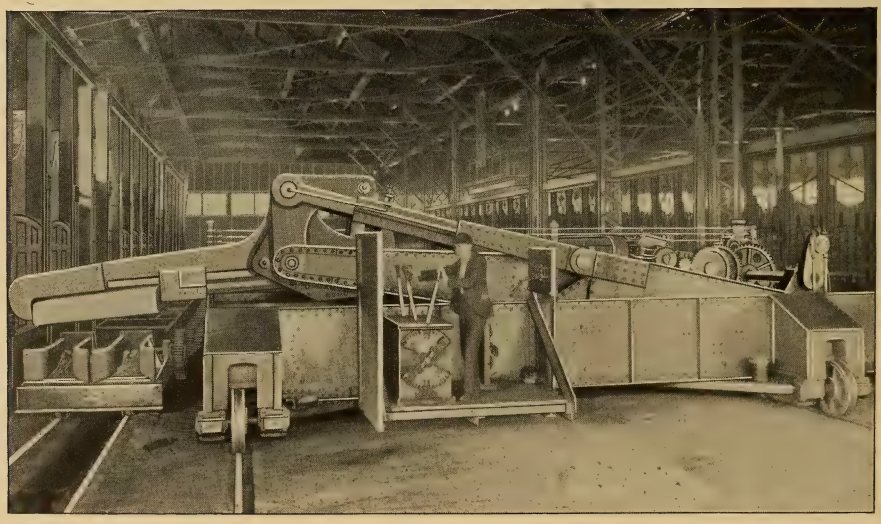
A HOT METAL MIXER

For work of this character vertical tongs, suspended upon, and made a part of, a specially designed electric travelling crane, are quite generally used. In addition to the usual movements of the crane the tongs are provided with powers of gripping, rotation, and vertical lift. With this machine a single operator unloads the steel as it comes from the converter and charges

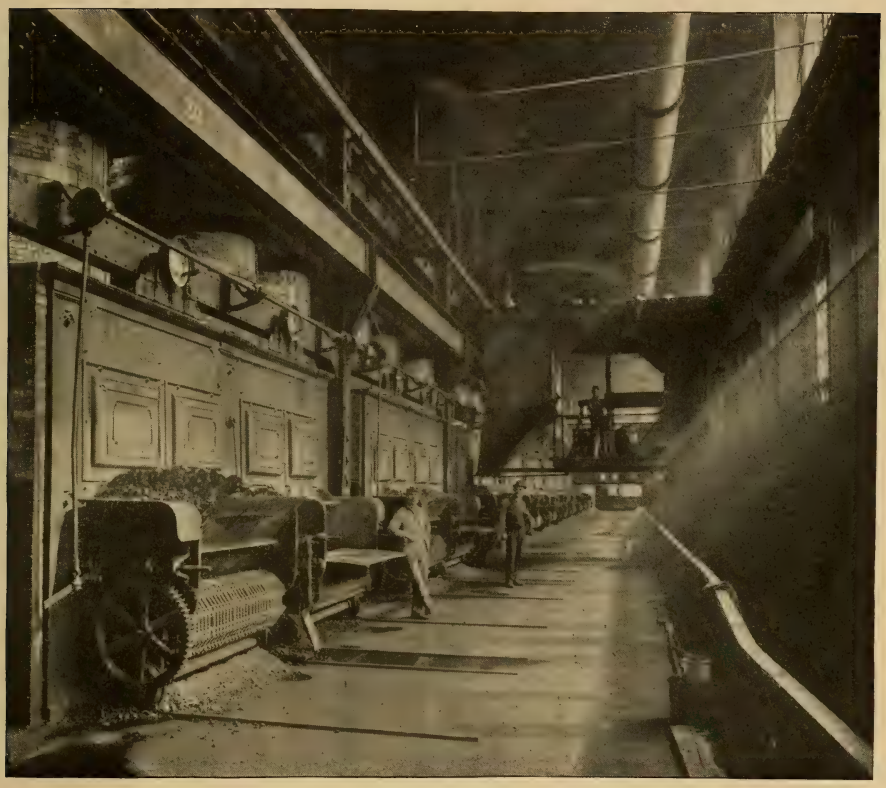
it into the furnace. By similar means the heated ingots are withdrawn and loaded into a transfer buggy for conveyance to the live roll runway leading to the blooming mill. There a maze of ponderous machinery, throbbing with gigantic power, and guided by invisible hands, transforms ingots into blooms and blooms into rails with marvelous rapidity. Twenty-seven hundred tons of rails, or enough to lay twenty-one miles of track, have been produced in a day by a single mill,—a performance all the more remarkable because accomplished under specifications demanding a compliance with a sectional variation of one-sixty-fourth of an inch.

In appearance, at least, there is little in common between the existing and the early rail mills. In olden times the rolling of rails resolved itself largely into a labour proposition. A large force was required and the exhaustive nature of the work necessitated the presence of many extra or spell hands. The mill was a teeming hive of sweating humanity, hauling, raising, and shoving the masses of white-hot metal from roll to roll, from pass to pass, with clumsy hooks and tongs, by very brawn and muscle. The morale of the labour employed was, as a rule, inferior to the average standard of to-day. The tendency was toward the development of brute strength rather than higher intelligence. Pay-day was the *bête-noire* of the mill superintendent, and a high thermometer was ever good cause for anxiety. Tonnage was low and practice irregular; costs were high and troubles regular.

The introduction of automatic machinery brought about a new order of things, and costs rapidly fell before increased production and decreased labour. The change was the means of temporarily throwing many out of employment, but the increased opportunities that were presented in the expansion that followed proved advantageous to labour as well as to capital. The rolling mill machinery that has replaced the former crude appliances is a monument to mechanical ingenuity and engineering skill. Massive and apparently unwieldy in design, it is yet delicate and accurate in its manipulation. Requiring but a few skilled mechanics for its operation, it is neither subject to the variation of temperature nor to the idiosyncracies of a large body of more or less irresponsible men. The driven runway, the movable table, the multi-



A HEATING FURNACE CHARGING MACHINE AT THE CARNEGIE WORKS, BUILT BY THE WELLMAN-SEAVER-MORGAN ENGINEERING CO., CLEVELAND, OHIO, U. S. A.

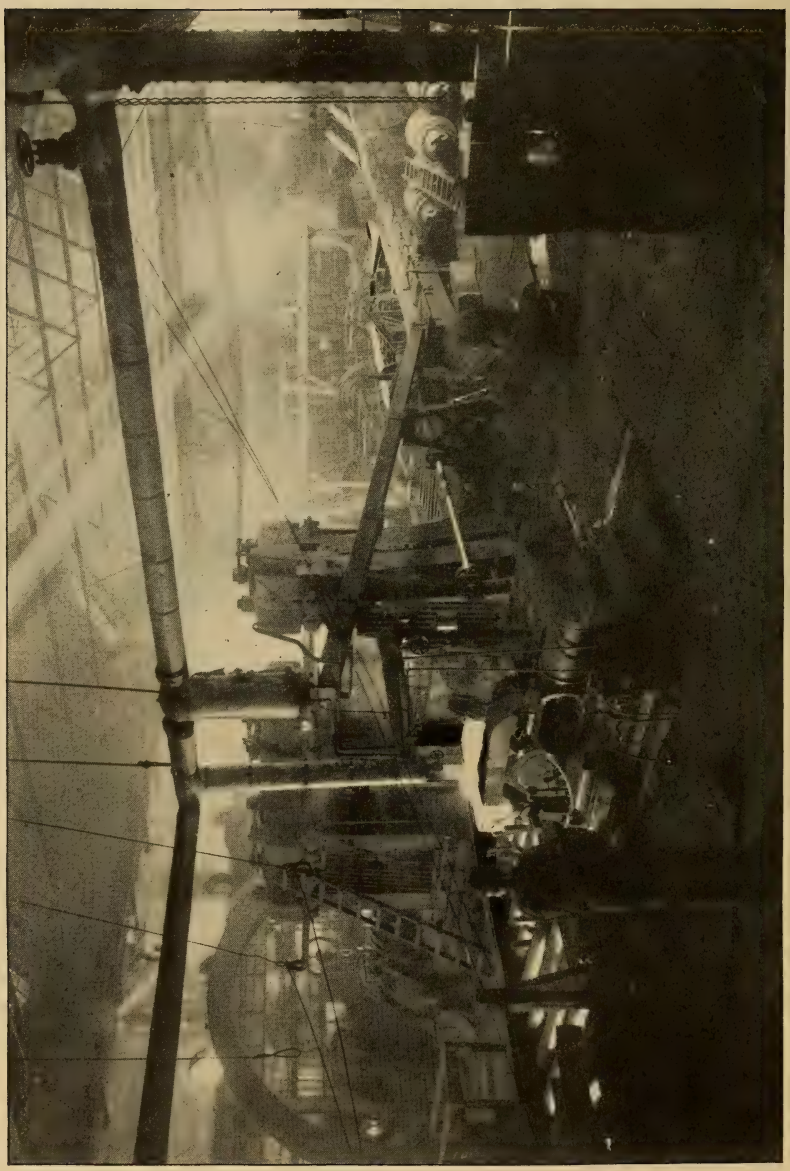


BOILER HOUSE AT THE DU QUESNE WORKS OF THE CARNEGIE STEEL COMPANY, PITTSBURGH, SHOWING CONVEYING AND STOKING MACHINERY

plication of rolls, the cambering machine, and the mechanical hot bed are some of the parts that have been introduced and have caused the former production of 200 tons a day to be increased twelvefold. Both by the intensity of production that has been permitted and by the reduction of labour that has followed the average result of a man's daily toil in the present rail mill is four or five times that of his predecessor.

Such work represents the expenditure of enormous power, and mill progress has made heavy demands on both engine and boiler-house design. How successfully they have been met is indicated by the extraordinary results obtained. A modern boiler house is an exemplification of concentrated power and refined economy. Conveyers mechanically charge the coal and remove the ashes; mechanical stokers have relegated the labourer and his shovel to the past, and high pressure and enlarged units permit the generation of steam in an efficient and well-nigh automatic manner.

Of the many elements entering into the complex organisation of a well-equipped plant those pertaining to the provision, circulation, and application of the water supply present many important problems. There are works consuming fully 90,000,000 gallons of water per day,—an amount more than enough to fill the requirements of some of the largest cities. The ordinary pump, scattered around in small and large units, is the rule rather than the exception. The comparative loss incident to the use of such machinery, consuming, as it often does, 100 pounds or more of steam per H. P.-hour, is as familiar as it is insidious. Concentra-



THE BLOOMING AND RAIL MILLS AT THE SOUTH CHICAGO WORKS OF THE ILLINOIS STEEL COMPANY. A HOT INGOT IS HERE SHOWN ON THE TABLE, A BLOOM AT THE SHEARS, AND RAILS IN THE ROLLS

tion of parts and the development of the triple-expansion, high-duty pumping engine have permitted great econo- took high rank as one of the most elastic and efficient of labour-saving tools.

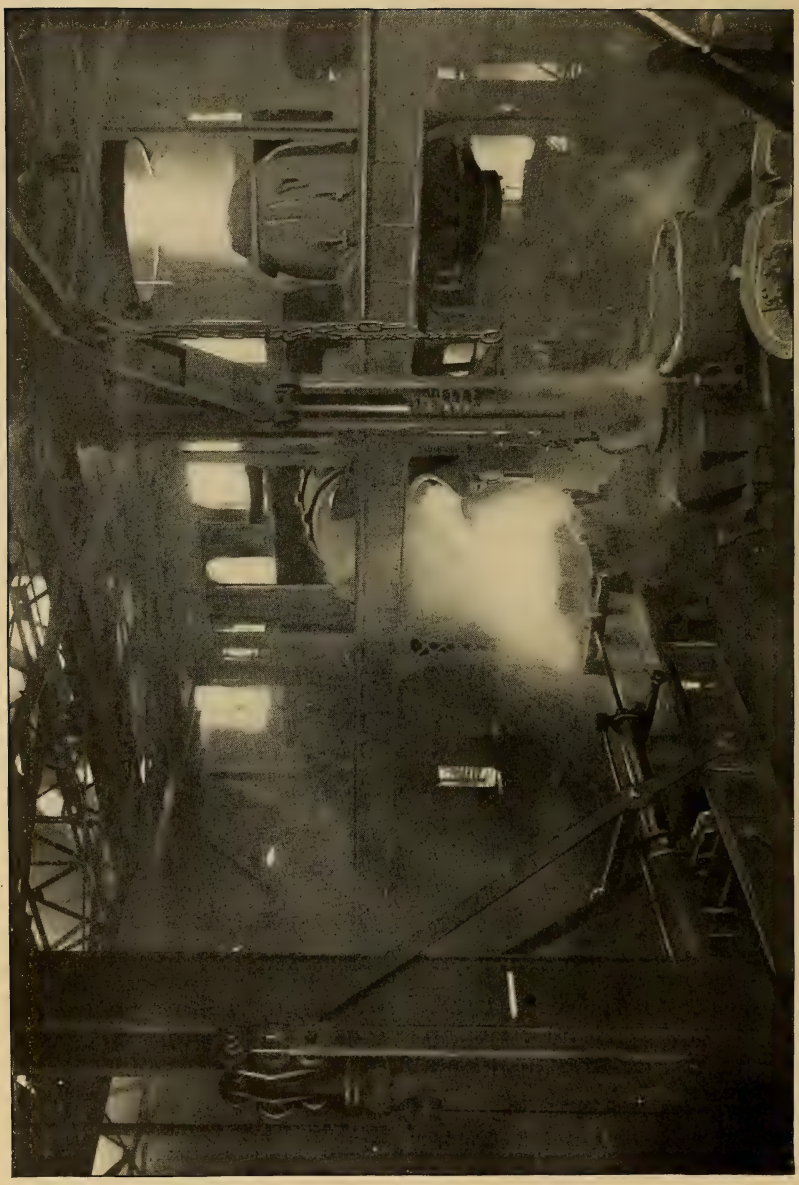
The use of the electric current in connection with work of an intermittent character and at small outlying stations has resulted in enormous saving, and manufacturers are rapidly availing themselves of the economies to be thus commanded. In rolling mills the introduction of the electric motor has been confined mainly to comparatively light work. Recent advances in the art, however, especially in the generation and use of the alternating current, promise to open up a much wider field, and indications now point to the installation of much larger units than have heretofore been considered feasible. Already there are several instances of small roll-trains driven by direct-connected motors, and the fact that this has been satisfactorily accomplished gives much food for thought. Electricity, from its flexibility, efficiency in transmission and low cost of maintenance, has rapidly won its way, and, as time goes on, gives fair promise of becoming more and more a factor in the manufacture of iron and steel.

ROD MILL AT THE JOLIET WORKS OF THE ILLINOIS STEEL COMPANY

my to those who have availed themselves of such installations.

In lighting and in power transmission much has been accomplished by the introduction of electricity. Year by year we find the electric power stations in the best plants rapidly expanding, and, from what has already been done, it is safe to assert that the entering wedge has hardly yet been driven. The possibilities of the electric crane, from its wide and extensive introduction, are too familiar to warrant more than passing reference. Almost from its inception it

In tracing the evolution of the rail, attention has been confined to the manufacture of pneumatic steel, but it is important to note the rapid strides that are being made by the open hearth process. The United States in 1900 produced a little less than three and one-half million tons of open-hearth steel and nearly double that amount of Bessemer steel. The output of open-hearth metal seems small in comparison with that of its rival, but statistics show that there has been a much greater proportionate gain in open-hearth steel



A BESSEMER CONVERTER BLOW

during the last few years than there has been in Bessemer. This is mainly accounted for by the development of the basic lining which has permitted the use of a wider range of raw materials than did the original process. This innovation would have been largely barren of results, however, had not such mechanical aids as the Wellman charging machine and the electric crane reduced what had previously been a practically prohibitive labour cost. As now constructed, there are good reasons for believing that the open-hearth furnace will continue to play a more important part in the world's metallurgical advance.

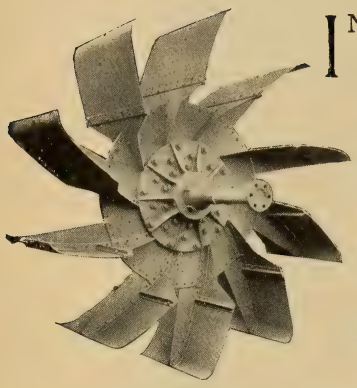
While the comparisons that have been made illustrate the general progress in staple lines, there are many specialties in connection with which improved rolling methods have been much more startling in their effect. In 1876 twenty tons were a fair product for twenty-four hours' work of a rod mill. The average daily wages of the men employed was $3.66 (14s. 3d.), and each man produced an equivalent of seven-tenths of a ton of rods. It is now no uncommon occurrence for a mill to roll 400 tons of rods a day, which is equal to over seven tons produced and $4.71 (18s. 10d.) earned per man. Thus the efficiency of rod-mill labour has increased tenfold, the product has grown from 20 to 400 tons per day, and the average wages earned are 30 per cent higher than they were twenty-five years ago. Surely this transformation is a striking commentary on the avidity with which the steel industry absorbs new ideas and utilises new devices. The Garrett mill, the automatic reel, the rod conveyor, and the continuous heating furnace are some of the potent elements that are responsible for these marvellous changes.

Any review of economic production, however brief, would be sadly deficient without allusion to the ethics of works management. The influence of labour-saving machinery has ever been towards intensity of intelligence, as well as intensity of production. As the standard of labour rose to a higher plane, former methods of management became obsolete. New conditions brought employer and employee into closer connection and forced greater dependence of one upon the other. Consolidation of plant and concentration of management have accentuated the necessity of continuity and harmony. This is recognised in the most progressive shops by the altruistic tendency. More attention is paid to the welfare of the workmen and greater endeavour is made to strengthen the relations between superior and subordinate. Profit-sharing, the club house, the hospital, and sanitary environment are some of the visible signs of that broad-gauge system that have proven it to be both humanitarian and remunerative to treat even the common labourer as a man and as a being capable of sensibilities and aspirations.

It may be difficult to directly measure the returns of this policy, but general results have shown that largely through such enlightened dealing both economy and production have arisen, Phœnix-like, from the ashes of discarded methods to the point of world-wide recognition and supremacy.

COLLIERY VENTILATING MACHINERY

By C. M. Percy, F. G. S.

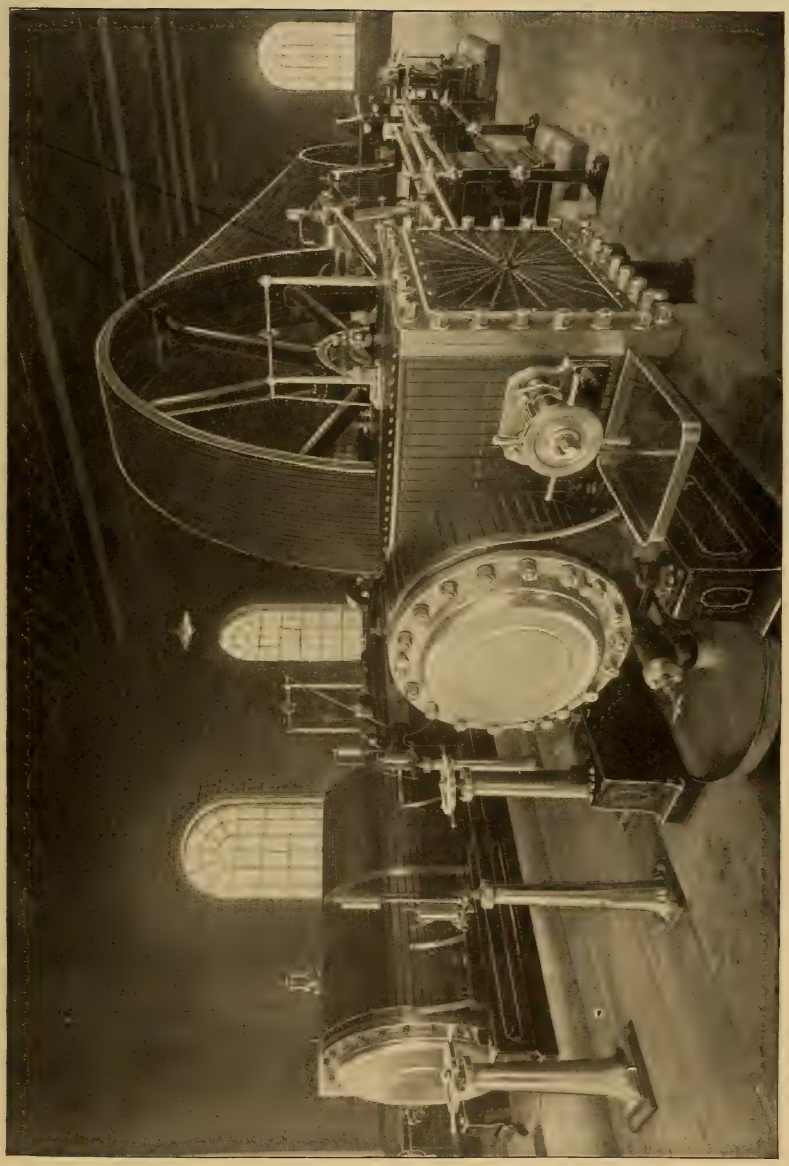


IN the operations of coal mining, which, in the United Kingdom alone, produce something over 225,000,000 tons a year, and find employment for nearly three-quarters of a million of people, there is nothing of more vital importance than the continual supply of a sufficient volume of fresh air for diluting the noxious gases prevalent in the mines and for enabling the underground workers to breathe a comparatively pure atmosphere. It may be said of modern mines that the efforts to provide this air have, in the majority of cases, been attended with so much success that the atmosphere of a modern coal mine is superior to the atmosphere of the forge or factory on the surface. The particular amounts of air required at the various collieries depend somewhat upon the nature of the mine, whether non-gaseous, or slightly gaseous, or very gaseous; also upon the number of human beings and animals employed in the mine; and on the amount of coal produced, which is not always in proportion to the number of persons engaged therein.

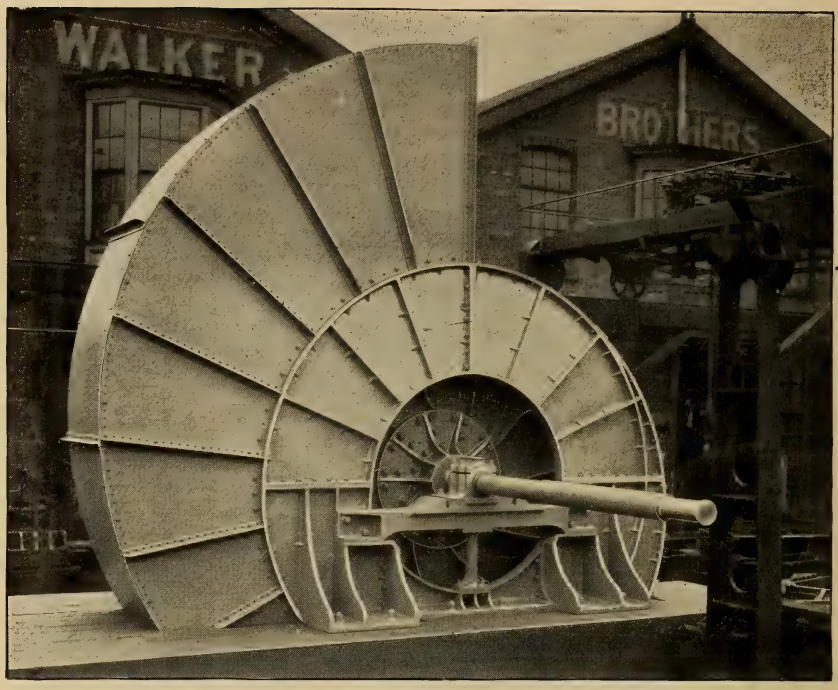
Taking all classes of coal mines, a fair and liberal consumption (and the allowance so as to be sufficient for all contingencies should be liberal), in the writer's opinion, is from five hundred to one thousand cubic feet of air per minute for each human being employed in the mine. Authorities differ very much as to the quantity, and even the lesser of the amounts stated will, in many quarters, be considered excessive; but they are not exaggerated amounts, and there are exceptional cases where even the larger quantity could, with advantage, be greater rather than less. Taking the total number of persons employed in and about the mines of the United Kingdom as three-quarters of a million, nearly 600,000 of this number will be employed underground, and the consumption of air, on the lower basis stated, for such an army of workers will amount to something like eighteen thousand million cubic feet per hour, representing in terms of weight more than half a million tons.

Making a comparison between the weight of the coal raised and the weight of air which passes through the mine in the length of a year, it has to be remembered that whilst coal production is not continuous, and in many cases occupies less than half of each twenty-four hours, and not always six days in the week, good ventilation at collieries means that the current is practically continuous from January 1 to December 31, day and night, Sunday and week day. Following out the figures given above, it is found that the weight of air which ought to pass through the mines of the United Kingdom in a year is not less than four thousand million tons, or something like twenty tons of air for each ton of coal produced. It is not too much to say that, taking the coal mines of the world, the weight of air passing through them for purposes of ventilation exceeds the weight of all the minerals raised, even if the generous, although necessary, maximum estimate of one thousand cubic feet per minute per individual be reduced one-half.

In the days of our forefathers, when the coal mines worked were very shal-



A GOOD EXAMPLE OF MODERN FAN ENGINE, ARRANGED FOR ROPE DRIVING. BUILT BY MESSRS. WALKER BROS., WIGAN



A FAN BUILT BY MESSRS. WALKER BROTHERS, WIGAN, ENGLAND

low and the output was very limited, the ventilation provided was trivial, and in not a few cases was obtained by the action of the mine itself, the difference in temperature of the atmosphere of the mine and of the atmosphere at the surface being sufficient to generate some current.

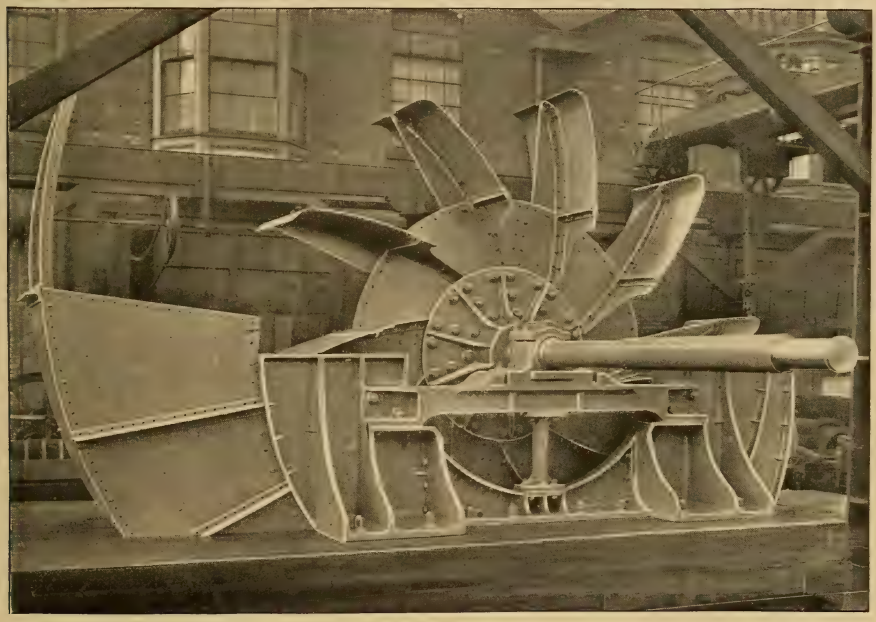
Coal mining is very different at the present day. Nearly all the mines in the United Kingdom are of considerable depth, measured in hundreds of yards. The great expense of putting down a colliery to such depths, and the cost of machinery to deal with coal from such depths, make a large output from a large area necessary, and require the employment in one mine of a large number of persons. Such a condition of things demands so large a volume of air for ventilation that it can be supplied only by artificial means.

In the first half of the last century what is known as furnace ventilation was almost universal. A large fire was maintained at the bottom of the outlet or upcast shaft, and the heat, acting upon the air in this shaft, caused expansion, diminishing the weight of the column in this shaft, and enabling the colder and heavier air in the inlet or downcast shaft to descend; thus a current was produced. This method of ventilation was effective and capable of very large volume, but was not economical; it also entailed danger from fire. As a matter of fact, very few such furnaces have altogether avoided setting on fire the coal in their vicinity, and they did not possess the facility necessary for maintaining a uniform current, or, when necessity required, for varying the volume expeditiously. During the latter half of the last century all methods of producing the ventilation of a colliery except the mechanical have been gradually falling into disuse, and practically all new collieries adopt machinery for this purpose.

That useful piece of machinery so common at every colliery, namely, the pump, had proved itself so excellent for dealing with volumes of water, however large, that it was not strange for some

of the first attempts with mechanical ventilators to proceed on those lines. These ventilating pumps were not measured in inches of diameter or even feet, but by yards, and were encumbered with numerous, and large, and heavy clacks or valves. The chief efforts in this direction were by Struve, and Goffint, and Nixon, and from experiments made, when working at a low speed and dealing with a small volume over a short period, seemed to give encouraging results; but the great size and weight of the reciprocating parts made anything approaching a high speed impossible; and the wear and tear of the valves and the machinery generally caused frequent stoppages for repairs. This latter defect was fatal; colliery ventilation cannot be effective unless it is continuous. It was not long after the first attempts at mechanical ventilation,—although a variety of contrivances were designed by Lemielle, and Fabry, and Cooke, and Root, and were constructed and worked with varying and inconsiderable success,—before it became evident that the effective machine, before which all others would disappear, was the centrifugal fan. This combined simplicity and practically everlasting wear, and efficiency with economy; and at the present time at least 90 per cent, of all the ventilating appliances at work are of the fan type. The fan is connected with the outlet or upcast shaft at the top of the shaft by a drift or airway entering that shaft at or just below the surface, and arrangements are made that no air can reach the fan except from the mine through the upcast shaft. The air enters the fan at one side, or both sides, the latter being preferable.

There have been discussions at times as to whether air should be forced into a mine at the downcast shaft, or drawn from a mine at the upcast; so long as we get the needed volume through the mine, however, it matters little which method is adopted. Although the large majority of colliery ventilators are exhausters, they might probably with equal advantage have been applied as pressure ventilators. In some special cases the arrangements made are such that the same fan can work either as



A VIEW OF THE FAN WITH THE CASING ABOVE CENTER LINE REMOVED

one or the other. In the pressure system we have a less volume, because nothing passes the fan except pure air, and the fan is not exposed to the corrosive influence of noxious gases. In the exhaust ventilator we have probably less pressure and strain upon the fan itself. The most reasonable explanation for the almost universality of exhaust ventilators is that, having no strong reason to the contrary, and the pioneer appliances, such as the steam jet and the furnace, having been associated with the outlet or upcast shaft, the modern appliance followed on the same lines.

The useful work of ventilation is represented by the volume of air that passes through the mine, and all leakage in from the surface to the fan is so much work lost; hence means have to be adopted to prevent air getting into the fan except from the mine, and special precautions must be taken, because air will so much more easily enter from the surface than through the long passages of the mine. The best modern practice is to use the outlet or upcast shaft for ventilation only, and under these conditions the course is clear and this shaft is covered over. But generally the outlet or upcast shaft is a regular winding shaft, and the arrival and departure of the cages complicate the situation and make some leakage inevitable.

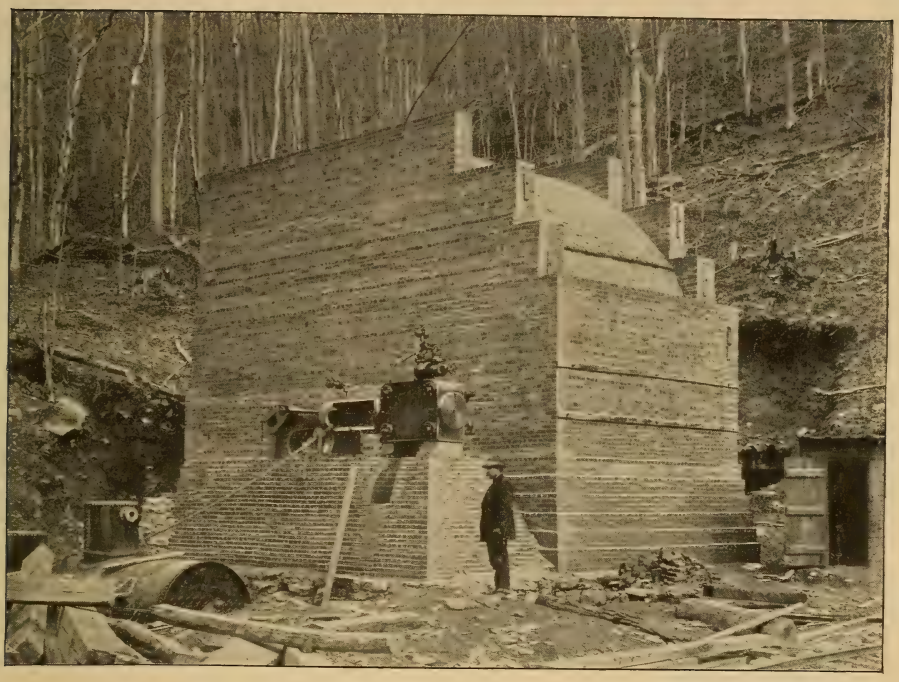
There seems no simpler or more effective plan under such conditions than that which was first introduced, namely, to enclose the pit framework and have on each side of that framework a commodious chamber for loading and unloading the cages. There are doors between these chambers and the pit bank outside, and there are doors between these chambers and the outlet or upcast shaft; these enable the cages to be loaded and unloaded without any serious leakage. It might be said that such an arrangement prevents the winding engineman from seeing the cages; but this is not necessarily so, because glass may be inserted and the electric light applied; and even if the winding engineman cannot see the cages, there is no difficulty with an effective code of signals, which in any case must be the only communication between the winding engineman and the cage at the bottom of the shaft.

The centrifugal fan easily separates itself into three great classes, namely, first, the open running; second, the close casing and enlarging chimney; third, the spiral casing terminating in a chimney; and as practically all the good ventilating machines used belong to one or other of these classes, this article will confine itself to them, the purpose being not to discuss all manner of ventilating machinery, but simply its most important and successful forms.

OPEN-RUNNING FANS

We include in the open-running class all fans which take air in on one side or both, and discharge it freely all round the circumference into the open. In Nasmith's arrangement there was simply a revolving wheel between two fixed sides, and a number of deep, rectangular, radial blades. The Biram fan was rather different, the blades being not nearly so deep, measuring only a tenth of the radius of the revolving part; that was a disadvantage. The blades also were inclined backwards, so that the root of one blade was in a radial line with the tip of the next blade; that was an advantage. In the Hopton fan the blades, which are of considerable depth, are arranged to curve backwards, and each blade passes tangentially into the circumference. The Marsden fan dispenses with blades, and the connection from inlet to circumference is by means of a number of tubes which curve backwards; the sides revolve with the fan.

A very popular form of open-running fan is the Waddle. The air enters on one side only, and the whole appliance revolves, thus making leakage at the sides impossible. The passage from the inlet, to the vertical plane of the fan, is curved, and the cross-section area of each division diminishes so that the circumference at any point, multiplied by the cross section area at that point, is a constant quantity. The blades or partitions, which incline backwards, do not extend to the periphery, and the



BRICK HOUSING MINE FAN MADE BY THE BUFFALO FORGE CO., BUFFALO, N. Y., WITH DIRECT-CONNECTED ENGINE BUILT BY THE LANE & BODLEY CO., CINCINNATI, OHIO, U. S. A. DIAMETER OF FAN, 25 FEET. WIDTH OF BLADES AT PERIPHERY, 10 FEET

space within the fan beyond the tips of the blades is bell-mouthed.

CLOSE CASING FAN AND ENLARGING CHIMNEY

Quite a number of different types of this class of fan have been introduced on the Continent of Europe, but the only one that has made any headway in the United Kingdom is that which bears the name of the Belgian engineer Guibal. We owe a great deal to this inventor and his invention. Previous efforts to introduce mechanical colliery ventilators had proved so far from successful that it almost appeared as if such men as Nicholas Wood and William Fairbairn were right when they stated that no machine could do for colliery ventilation what furnaces were doing. The Guibal fan was from the first a substantial success. The air enters on one side, or both, and the blades, which are deep and rectangular, incline backwards, and curve at the tips radially with the circumference. The casing is a fixture, and comes within simple clearing distance all round the circumference except for about a tenth of the whole, near the bottom. This opening, which can be increased or diminished by a sliding shutter, delivers into a chimney which increases in cross-sectional area to the top. There is no doubt that the success of the Guibal fan was, and is, due to its chimney.

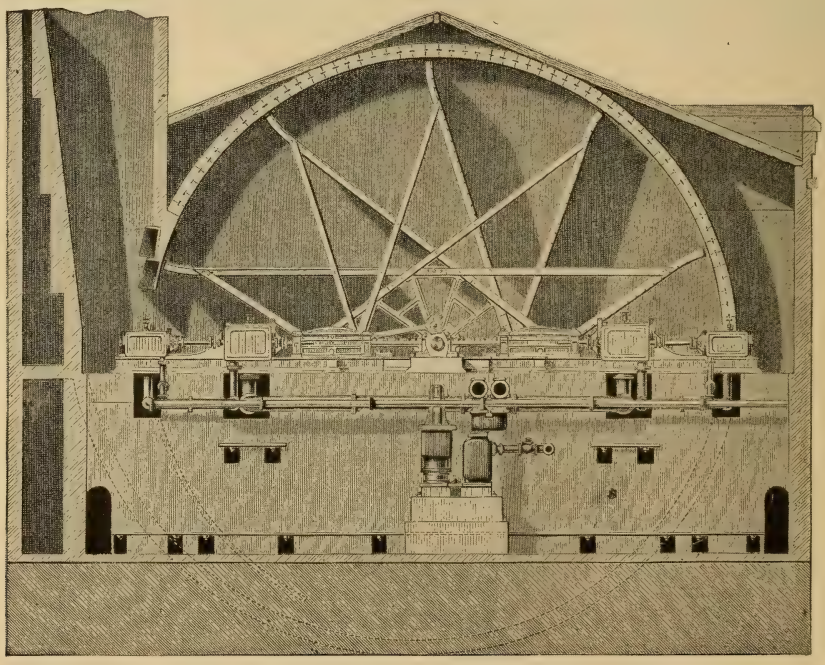
Recognising that the air must leave the revolving part of the fan at a high velocity, representing so much energy, the enlarging chimney receives the air at that high velocity, and, by its increasing area, diminishes the velocity, and utilises the liberated energy in overcoming all pressure within the chimney and actually producing a partial vacuum. A twofold benefit arises,—the delivery from the fan itself is expedited because resistance is removed; and the air passes easily out of the chimney into the open.

There have been at least two distinct improvements in the original Guibal fan. Cockson modified the form of the

blades so as to give a uniform passage for the air through the fan, and to make the pressure uniform on the blade. Messrs. Walker Brothers, of Wigan, modified the shutter, which, being rectangular, caused each blade to lose all its pressure instantaneously, producing as many shocks and vibrations in each revolution as there were blades. This caused a good deal of wear and tear, and limited the speed. The Walker anti-vibration shutter, formed like a reversed elongated letter V, so Λ, avoids absolutely the shock of each blade passing the shutter; this made a considerable increase of speed,—therefore volume and water gauge,—possible with less wear.

SPIRAL CASING FANS

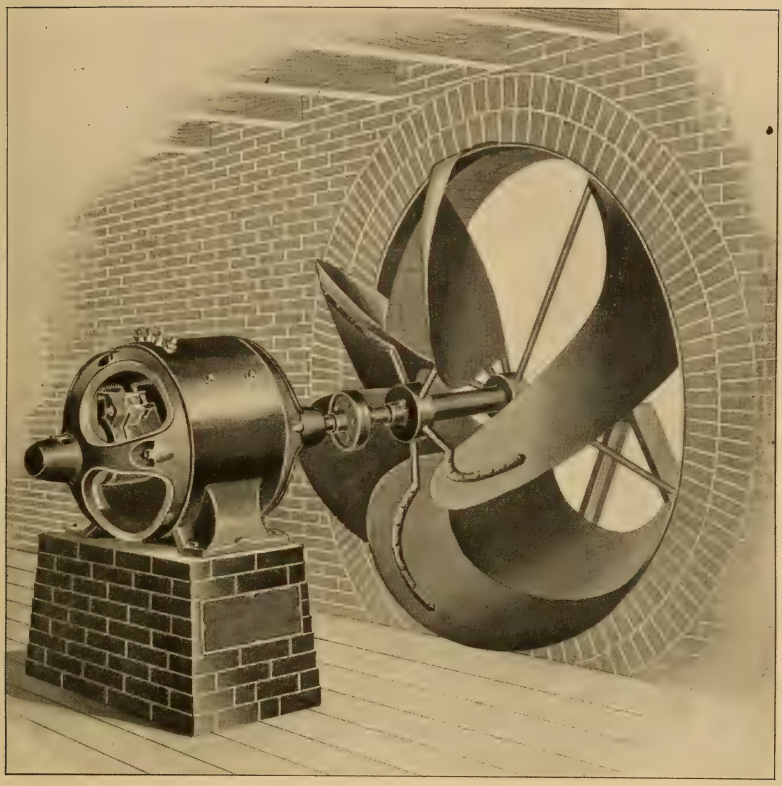
In these fans there is a spiral casing which affords an opening from the re-



A 46-FOOT GUIBAL FAN WITH COMPOUND ENGINES, IN DUPLICATE. BUILT BY MESSRS. WALKER BROTHERS, WIGAN

volving part all round the circumference, the cross section area of the spiral casing increasing to the chimney. The Schiele fan, which appears to have led the way in this class, has blades slightly curved backwards at the tips, just the reverse of the Guibal. The other portion of each blade is straight and inclined backwards, and the edges are so formed that the passages through the fan maintain a uniform cross-section area from inlet to circumference.

What is known as the Walker "Indestructible" fan has been before the mining community for many years, and, so far as the United Kingdom is concerned, more fans of this class than of any other have been applied at collieries. The chief points aimed at by the makers were to produce a ventilating machine which should obtain a high percentage of useful effect, without the great weight, unwieldy dimensions, or expensive foundations of the large direct-driven fans; and which should possess the strength, rigidity, and durability of the smaller fans whilst avoiding their excessive speed and probable trouble with heated bearings. There are two strong cast-iron bosses, carefully bored out and



AN ELECTRICALLY-DRIVEN MINE VENTILATING FAN MADE BY THE MASSACHUSETTS FAN CO., WALTHAM, MASS., U. S. A.

made a good fit on the fan shaft, to which they are secured by steel keys. The extension lengthwise of these bosses distributes the weight of the fan over the shaft. Between the bosses are two discs of steel which fit the fan shaft. Each disc is in halves, the joints being placed at right angles, thus forming one double disc of great strength. Between the two discs the iron arms of the fan are fixed "sandwich"-like and gripped tightly. These arms extend from near the axis of the fan to its periphery, the discs supporting them half-way. Angle irons are riveted to the fan arms beyond the discs, and to these angle irons the blades, usually eight in number, are firmly secured. The blades, which spring tangentially from a small circle concentric with the fan shaft, are curved longitudinally, to the arc of a circle of a certain radius, and are cut away from the edge of the inlet of the fan shaft, to minimise central resistance.

It is very necessary to minimise the slipping of the air between the sides of the blades and the walls of the fan chamber as far as practicable. The blades, being strong, cannot be brought close to the walls, as in the event of any side movement of the fan on its bearings they might "catch." The clearance, therefore, is made up by attaching strips of pliable hoop iron to the sides of the blades.

The Walker anti-vibration shutter (although a spiral casing surrounds the fan), referred to elsewhere in this article, is applied with effect to this fan. It may be of interest here to relate that several years ago Messrs. Walker Brothers had erected three ordinary Guibal fans for ventilating a portion of the London Metropolitan Underground

Railway, and, although the fans were effective enough in producing volume of air, the pulsations or vibrations exercised an injurious influence upon the windows and doors of the surrounding buildings, and unpleasant proceedings were threatened. The application of the anti-vibration shutter saved the situation in this particular case, and the appliance has now become a useful appendage to ventilating fans at hundreds of collieries. The Capell fan has two parts revolving together, the inner part being really a drum with openings in the circumference, and the outer part being open to the spiral casing. The blades are curved backwards in each part, and the claim is that there is a utilisation of energy not only between the outer part and the spiral casing, but also between the inner part and the outer. There always seemed to be room for doubt as to whether this double endeavour to utilise this energy was necessary or desirable, and later improvements would appear to be on lines depending on the conversion of the energy at one operation between the fan and the casing and chimney into which the air discharges. The chimney of the Capell fan differs from the Guibal as the cross-section area increases more rapidly; in the former the enlargement is on two sides, whereas in the Capell the enlargement is on all four sides.

The advantage of the open-running fan is its simplicity, and there is no elaboration of the surrounding structure; the air is not obstructed in leaving the fan at any point of the circumference. But the inseparable defect would seem to be that the air cannot avoid leaving the fan at a high velocity, and the energy represented in this velocity may be very serious and is wasted. In the close casing and the enlarging chimney this is avoided. The defect of the close casing would seem to be that it prevents free outlet for the air, and forcing some of the air through nine-tenths of the circumference against its natural inclination must generate friction and absorb work. Also there must be an increasing pressure on each blade from the time of passing the outlet to arriving at it again, and such an inequality of pressure does not encourage high speed.

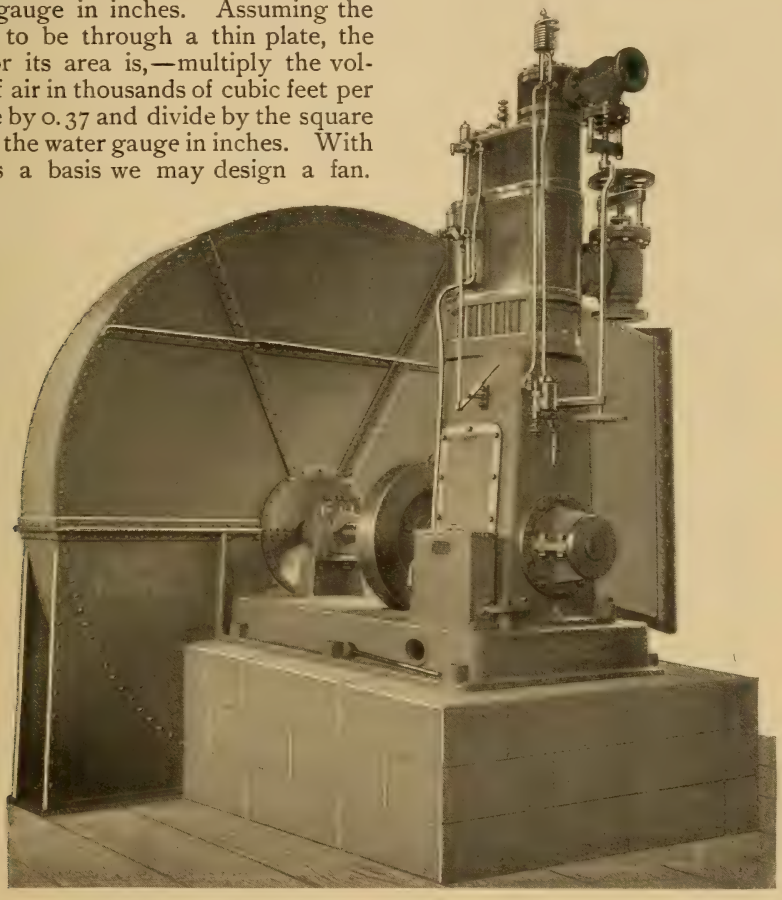
The fan with the spiral casing terminating in a chimney would appear to combine whatever is advantageous in the two other classes, and avoids their defects. The spiral casing affords free outlet from the revolving part of the fan all around the circumference, and extends the advantages of the enlarging chimney for diminishing velocity and utilising energy all around the circumference.

Opinions differ as to the correct form of fan blades. It seems right that the passage for the air through the fan should be in as direct a line as may be. Mere revolution means simply "churning" the air and setting up frictional resistances. A particle of air moving radially along a revolving disc traces a line more or less curved backwards, according to the speed of revolution of the disc and the radial speed of the particle; and this backward curved line will pass easily into the circumference. That would appear to be the correct form of the blades, and in the open-running fan that should be the form of the blades; but in the close-casing fan, such as the Guibal, this would hardly apply, because the air, however it travels from the inlet, can leave the fan only at the place provided. And it is probably not of very great importance in the fan with the spiral casing, because whatever velocity the air may possess in leaving the fan is taken from it before being discharged into the open. Still, any change in form of fan blades from the radial should be backwards and should be curved.

When ventilating collieries by machinery was new and there was no experience to guide the makers or purchasers, a good deal of constructing was done by rule of thumb. But years of experience with many thousands of ventilating installations under all possible conditions have enabled the laying-down of fairly accurate practical rules of design.

It is quite evident that no fan, however excellent, will produce a current

unless the passages in the mine will allow the air to get to the fan. Strange as it may seem, many mines have excellent fans, but deplorably poor airways. What is called the "equivalent orifice" of a mine is the smallest area in square feet which will pass a given volume of air in a minute with a given water gauge in inches. Assuming the orifice to be through a thin plate, the rule for its area is,—multiply the volume of air in thousands of cubic feet per minute by 0.37 and divide by the square root of the water gauge in inches. With this as a basis we may design a fan.



A VENTILATING FAN WITH DIRECT-CONNECTED HIGH-SPEED ENGINE BUILT BY MESSRS. BUMSTED & CHANDLER, HEDNESFORD, ENGLAND

Each of the two inlets should be equal to the "equivalent orifice" so as to make allowances for resistances within the fans, and the passage through the fan should be equal in area to at least that of the inlet or inlets.

It will be seen that for a given volume the "equivalent orifice" will be larger for a low water gauge and smaller for a high water gauge. The writer has assumed a medium water gauge for mines in the United Kingdom of two and a half inches, and has also adopted two inlets, each being equal to the "equivalent orifice." Laying down a practical rule that each inlet shall equal the "equivalent orifice," that the fan shall have a diameter equal to twice the diameter of the inlet, and that the width of the fan shall be approximately one-third of the diameter of the fan, we arrive at the results given in the table on page 404.

With proper conditions, the water gauge will depend upon the speed of the circumference of the fan,—will, in fact, increase and decrease as the square

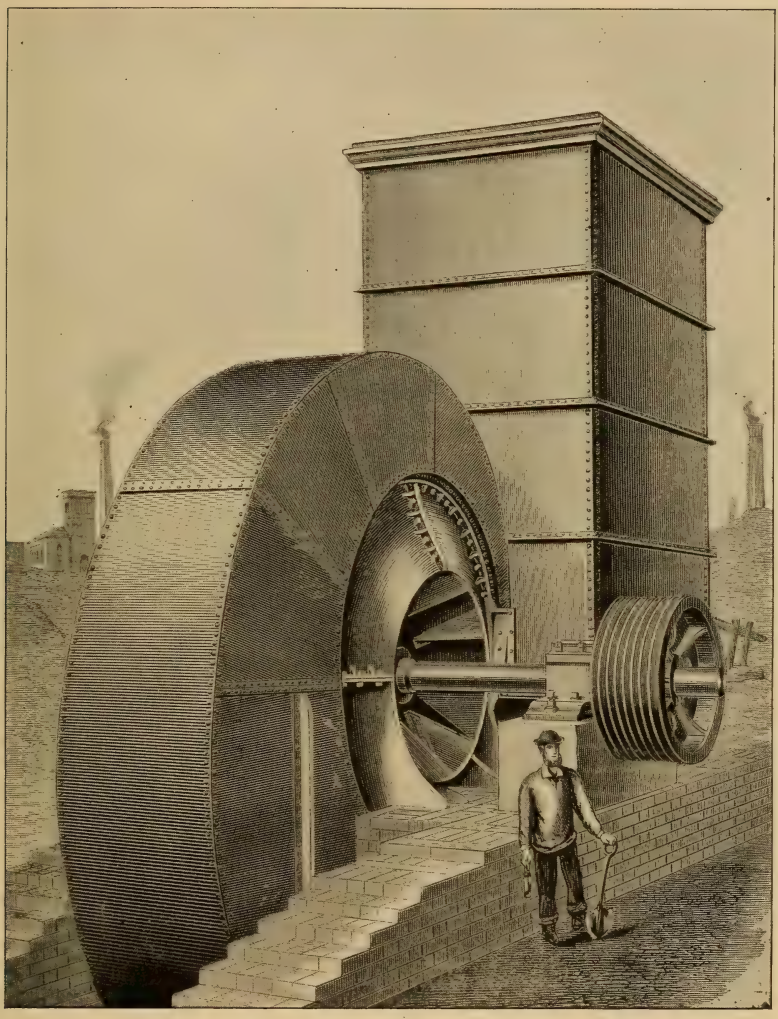
of the velocity. The water gauge itself is a bent glass tube, open at both ends

Cubic Feet of Air per Minute.	Diameters of Each of Two Inlets. Feet.	Diameter and Width of Fan. Feet.
50,000	4	8 × 3
100,000	6	12 × 4
200,000	8	16 × 6
300,000	10	20 × 7
400,000	12	24 × 8
500,000	13	26 × 9
600,000	14	28 × 9
750,000	15	30 × 10

and fixed vertically, one end connecting with the open atmosphere, say, in the engine house, and the other end with the airway or drift leading to the fan, and preferably, for accuracy of result, sufficiently far removed from the fan itself to be free from contending currents and eddies which are unavoidable in the inlet, or close to it. There is water in this appliance, and the influence of the fan lifts the water in one leg and depresses it in the other. Of the difference in level, each inch represents a pressure of 5.2 pounds per square foot, being simply the weight of a column of water one inch high and a square foot in area. Knowing the speed of the circumference of the fan in feet per second, we square it, and divide by 64, which gives us the ventilating column in feet. Brought into inches and divided by 800 (because water is practically 800 times heavier than air at atmospheric pressure), we arrive at the water gauge in inches for a given speed of circumference of the fan. The friction of air increases as the square of the velocity; therefore the water gauge produced increases with the square of the speed of the fan. The power has to overcome increased friction and increased volume; therefore the power increases as the cube of the speed of the fan. The horse-power of ventilation is the quantity of air in cubic feet per minute multiplied by the water gauge in inches and by 5.2 and divided by 33,000. The usual effect or efficiency of a fan is the proportion of the power consumed to the power of the fan engine.

The general method of arriving at the efficiency leaves much to be desired. The power of the engine usually taken is the indicated horse-power, which includes the engine resistances, representing perhaps 20 per cent. of the indicatep power. Why should a fan be charged in its balance sheet with power that it never receives, and how can we compare two fans on these lines, if one has a good engine and the other has a bad engine? The engine power should be the useful work which an engine has available after accounting for its own resistances, which resistances are rarely the same in any two engines. Then, again, the water gauge is often not taken with sufficient accuracy, and, still further, the actual volume of air passing is not known because the linear velocity is not measured correctly, and the same remark applies to the area of the passage leading to the fan. There is much to improve upon in determining the useful effect or efficiency of a fan. The method laid down in this article for determining water gauge from speed, or speed from water gauge, is not that which is usually adopted and which gives a water gauge twice as great as here set out; but the water gauge obtained by modern rules is the "manometric depression" or theoretic efficiency of a fan; and as the water gauge in practice is rarely more than one-half of this theoretic quantity, the rule followed in this article is not necessarily in contradiction, and simply brings us to the actual and practical water gauge obtained by a fan by a shorter route.

So far as the fans themselves are concerned there are now any number of admirable examples, excellent in design and construction, capable of running with absolute truth upon their bearings with a minimum of resistance, and also of running continuously for many years without any necessity of stoppage for repairs. The method of driving, however, is not nearly so universally good. There are, it is true, some very good examples of fan engines, but the majority are not of that kind. The extravagance of colliery machinery generally is not a creditable feature of the age. In connection with one important class,—winding engines,—some excuse can be found for it. Such engines work intermittently, rarely for as long a period as a minute for a journey; start from rest



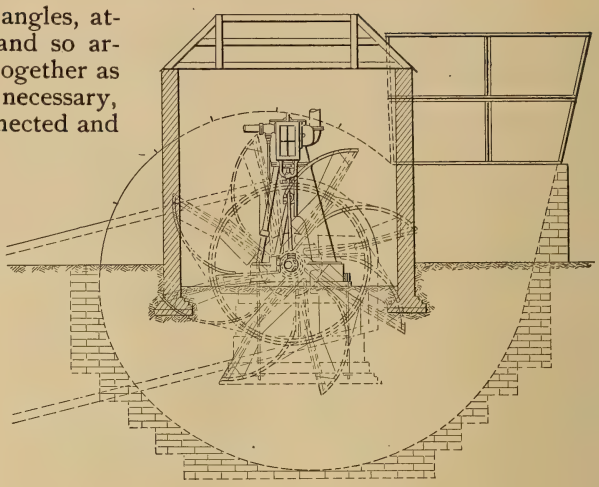
A SCHIELE FAN ARRANGED FOR ROPE DRIVING. BUILT BY MESSRS. WALKER BROTHERS, WIGAN, ENGLAND

and reach a high speed, then fall away from that high speed to rest,—all within this just-mentioned short period; and they must be easily capable of starting from and stopping at any point. But even with this class of engines improvements are being made, and condensing and compounding are being introduced.

With ventilating machinery the work is almost absolutely uniform and continuous, without stoppage, day and night, from January to January. Such a condition of things invites and encourages all that is perfect in the economics of engineering. But it would be no exaggeration to say that a considerable proportion of fan engines are still not only non-condensing, but only very slightly expansive. An engine of that type will consume from six to eight pounds of coal per horse-power per hour, as compared with a pound and a half of coal per horse-power per hour in a truly economical engine.

The best arrangement of engines for driving a fan would probably be a pair of horizontal, triple-expansion condens-

ing engines, placed at right angles, attached to separate cranks, and so arranged that they can work together as a pair, or, if repairs should be necessary, one engine could be disconnected and the other engine alone continue to drive the fan. If the first expense could be met, an even better arrangement would be to have two distinct and self-contained ventilating plants, so that with two fans and two engines there would be opportunity for overhauling one fan and one engine without interfering with the ventilation. There is at least one colliery known to the writer at which such an arrangement has been adopted.

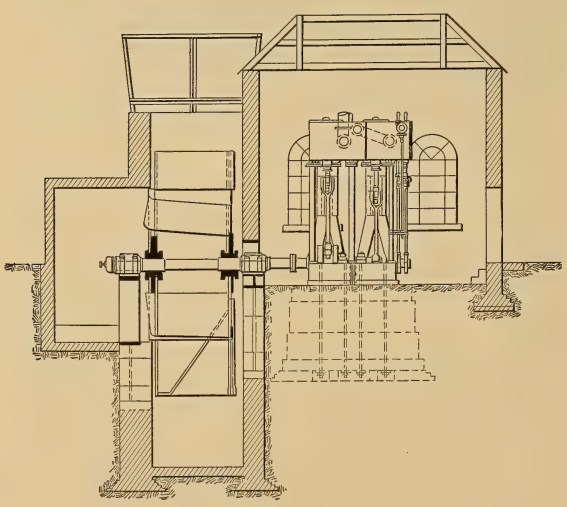


A CAPELL MINE FAN WITH COMPOUND VERTICAL ENGINES. BUILT BY MESSRS. THWAITES BROS., LTD., BRADFORD, ENGLAND

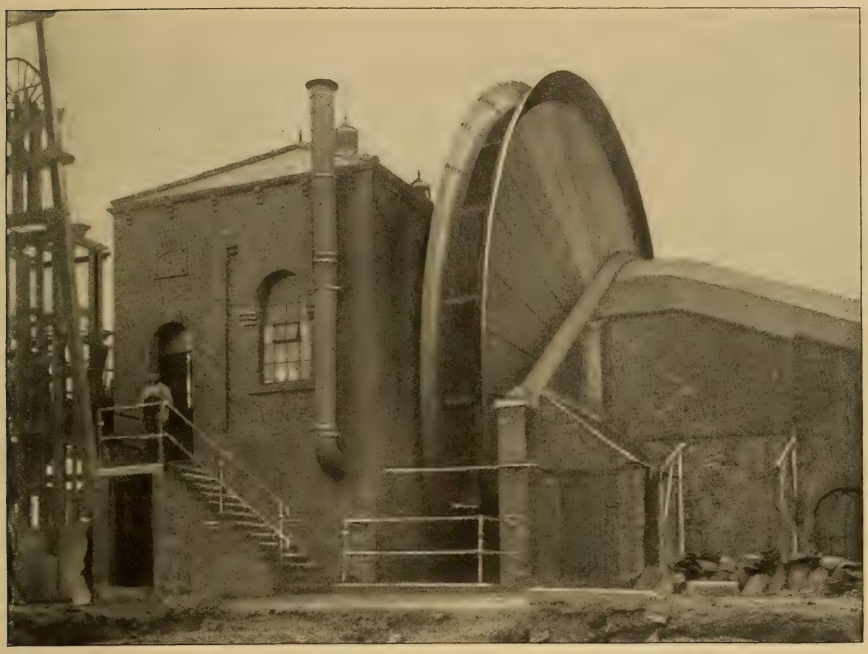
In the early mechanical ventilators, which were usually on a large scale, and did not make a great number of revolutions per minute, the engine was connected direct to the fan, and this caused a twofold defect as time went on. Either the engine had to run very quickly indeed, which is not desirable even now when running continuously for months, or the fan had to be made very large in diameter to obtain a sufficient circumferential speed. The massive fans of a quarter of a century ago, of 45 feet and even 50 feet in diameter, were cumbersome structures, requiring large and expensive foundations, and absorbing much power simply to keep them in motion.

It has been proved that in coal mining practice such mammoth sizes are not necessary as regards volume. A million cubic feet of air per minute at the ordinary water gauges can be produced with a diameter of 30 feet, and no one mine is likely to need so much; and as regards the amount of depression or water gauge required, that depends not on the diameter, but on the speed of the circumference. A fan 5 feet in diameter, running at 500 revolutions per minute, will have the same speed of circumference, and therefore produce the same water gauge, as a fan 50 feet in diameter running fifty revolutions per minute.

The best modern practice is to run the fan engine at a moderate speed, say, 400 piston-feet per minute, and to get up the requisite speed in the fan by gearing. Spur wheels have nothing to recommend



ANOTHER VIEW



A 45-FOOT FAN AT SOUTH MOOR COLLIERY, INSTALLED BY THE WADDLE PATENT FAN & ENGINEERING CO., LLANELLY

them except their positive action, which, with a fan, is not absolutely essential. Straps have answered well enough, and are fairly noiseless, but there is a difficulty in the transmission of large powers in obtaining straps of a reliable quality and sufficiently flexible. Round cotton ropes, usually about 1½ to 2 inches in diameter, running in carefully prepared grooves, answer admirably; there is scarcely any wear and tear upon the ropes, because, as a large number is usually applied to drive the fan, the amount of pull on each single rope is only slight. The ropes give a better grip even than flat straps, and, if anything, are more free from noise in action.

The speed of the fan depends altogether on the amount of depression or water gauge required, which in the mines of the United Kingdom does not often exceed about 4 inches, unless in exceptional parts of the mine, where small auxiliary fans may be applied. But all well-designed and constructed fans of the present day should be capable of running without injury at a circumferential velocity of, say, 12,000 feet a minute, which would obtain a water gauge of nearly 12 inches. There is really no difficulty in speed, so far as the fan itself is concerned; that is merely a question of sufficient strength, accurate balancing, and true bearings. There have been difficulties in keeping the fan shaft journals from heating, but those difficulties are disappearing before modern mechanical engineering improvements.

It will have been gathered from this article that in the United Kingdom no ventilating machine has been largely and successfully applied to collieries except the centrifugal fan, which, being a simple wheel, if made strong enough and properly balanced, can run at any reasonable speed, and has really nothing to get out of order. These fans should be of moderate dimensions; a diameter of 30 feet might be taken as a maximum for a volume extending to, say, three-quarters of a million or even one million cubic feet per minute. There

should be two inlets to each fan; the diameter of the fan might be taken for any particular case as twice the diameter of the inlet; and the width one-third of the diameter of the fan, which should be driven by a pair of triple-expansion engines transmitting their power through rope gearing.

The fan should be of the class with spiral casing terminating in a chimney, and should have a strong central diaphragm, preventing the meeting of the currents from the two inlets. Such an arrangement might be used effectively either to force air into the inlet or downcast shaft, or to draw air out of the outlet or upcast shaft, and in either case careful means should be adopted for sealing the pit shaft at which the fan is placed, so that, if situated at the downcast shaft, there is no passage other than through the fan, and, if located at the upcast, also no means of communication except through the fan. The water-gauge appliance, for measuring the effective depression, should be a few yards distant from the fan itself; the useful effect or efficiency of the fan should be based not upon the indicated horse-power, but the useful horse-power of the fan engine. The colliery manager or mining engineer should not be content with providing ventilating machinery of the highest character, but should remember that as no pump can deal with water unless the suction passages are clear, and as no winding engines can raise a load unless the rope is attached to the cage, no fan can do justice to itself or its owner unless the passages in the mine are sufficient to allow the air to reach the fan.

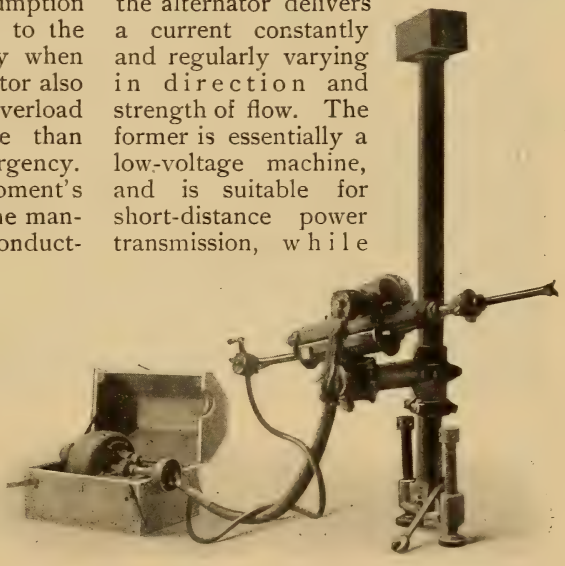
ELECTRICITY IN MINING

By William B. Clarke

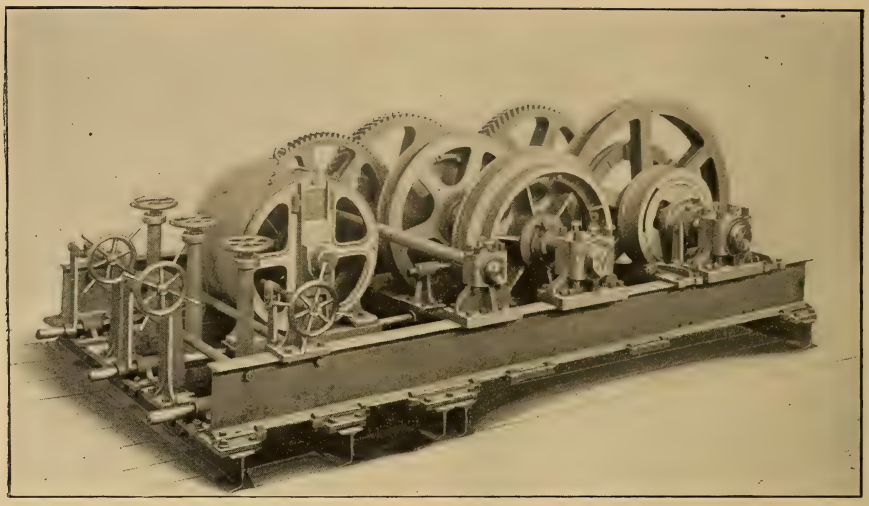
Mine locomotives, hoists, air compressors, drills, pumps and much other mining machinery are at the present time driven electrically, and there is promise of still wider application of electric power in the mining field. Mr. Clarke's article, therefore, might reasonably be expected to cover this whole range of electric power uses, were it not for the fact that the magnitude of the subject compelled dividing it up into sections, each handled independently by a specialist in that particular branch. Thus, articles will be found in this issue dealing with electric underground haulage, electric coal cutting, compressing air, mine ventilating, and others, and Mr. Clarke's contribution accordingly had to be restricted principally to those features not so presented. With this explanation, it may well be left to speak for itself.—THE EDITOR.

THE conditions which attend the development and the consumption of power for operating mining plants, constitute a field to which the electric motor seems to be especially adapted The motor, to begin with, is very simple, notwithstanding the mystery that, in the popular mind, sometimes surrounds electrical apparatus. One of its principal advantages is its fundamental rotary motion, with no "dead points" requiring heavy flywheels. It is capable of perfect control, which adapts it to service of an intermittent nature, while its high efficiency permits of the most economical performance of constant work. The consumption of energy is always proportional to the actual load, and ceases entirely when the work is stopped. The motor also possesses a great momentary overload capacity, safely carrying more than double its normal load in an emergency. It is ready for service at a moment's notice, responding instantly to the manipulation of the controller; the conducting wires are flexible, and readily follow the convolutions of the mine workings; and extensions and changes, finally, may be quickly and cheaply made, — a statement by no means true of any system of piping. As compared with compressed air, the principal advantage of electricity lies in its greater efficiency and flexibility. Electrical apparatus may be installed, even in comparatively small units, with a guaranteed efficiency of 75 per cent., including the losses in the dynamo, transmission line, and motor, —obviously conducive to comparatively low investment charges and operating expenses.

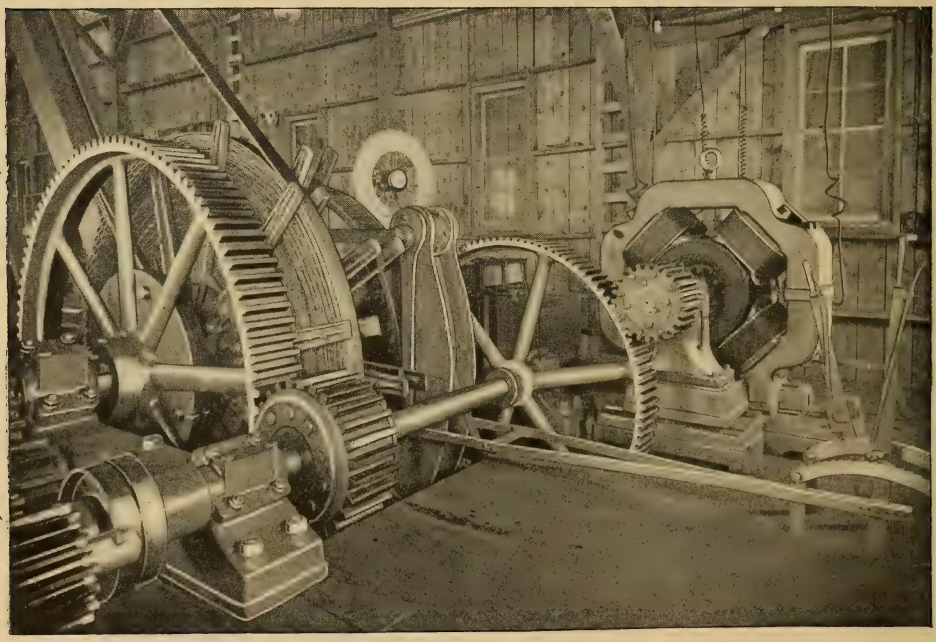
The generator and transmission line are component parts of the electrical system, as important and interesting as the motor. Electric generators or dynamos are divided into two distinctive classes, according to whether their output is direct current or alternating current. The direct-current dynamo generates a uni-directional current, while the alternator delivers a current constantly and regularly varying in direction and strength of flow. The former is essentially a low-voltage machine, and is suitable for short-distance power transmission, while



A PERCUSSION DRILL DRIVEN ELECTRICALLY THROUGH A FLEXIBLE SHAFT. MADE BY THE MINE & SMELTER SUPPLY CO., DENVER, COL., U. S. A.



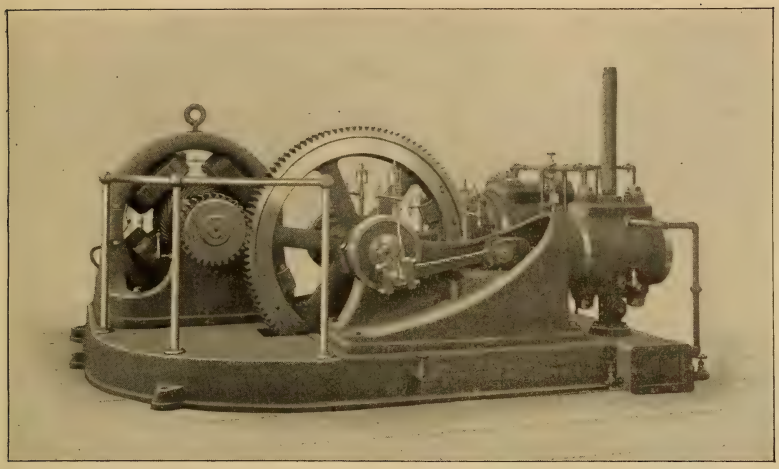
ELECTRICALLY-DRIVEN COLLIERY WINDING GEAR, MADE BY MESSRS. J. P. HALL & CO., OLDHAM, ENGLAND



A 100-KW. ELECTRIC HOIST, INSTALLED BY THE GENERAL ELECTRIC COMPANY, OF NEW YORK, AT THE FREE SILVER SHAFT, ASPEN, COLORADO, U. S. A.

the voltage of the alternator may be as high as 12,000; or the voltage may be low and may be raised by means of step-up transformers. The practical value of the higher voltages may be appreciated from the fact that for transmitting a certain amount of power a certain distance, the cost of copper for the transmission line varies inversely as the square of the line voltage.

The direct-current system for several years occupied the field alone, and the



AN ELECTRICALLY-DRIVEN AIR COMPRESSOR, MADE BY THE INGERSOLL–SERGEANT DRILL CO., NEW YORK AND LONDON

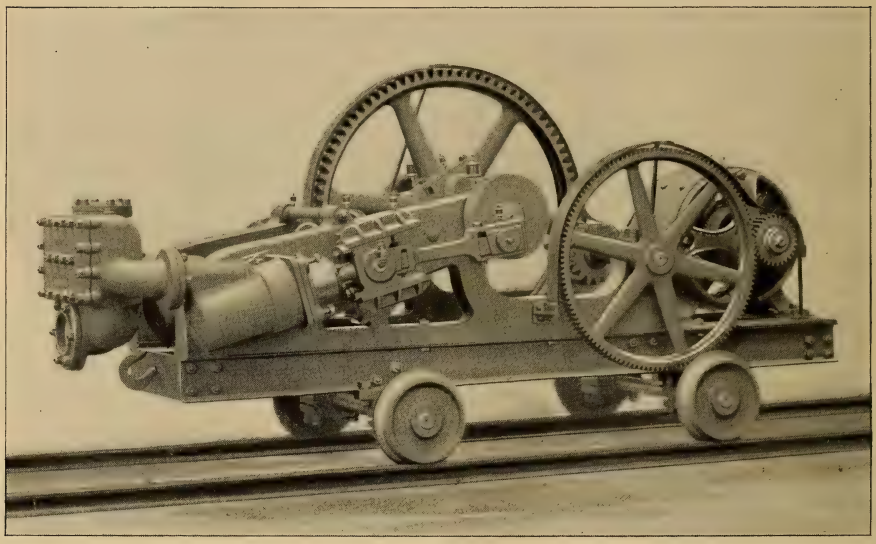
earlier electric power plants were in that class. The voltage with this is limited to about 600, and the economical distance of transmission of moderate amounts of power seldom exceeds three miles. Beyond that distance either the interest on the copper investment or the cost of the energy lost in transmission becomes prohibitive. For mine haulage the direct-current system is preferable, as no suitable alternating-current traction motor has yet been developed on a commercial scale.

Where locomotive haulage is the principal application of electricity, as in many coal mines, the direct-current system should be adopted with a voltage of 250 or 500, the copper investment for the higher voltage being one-fourth as great as for the lower voltage.

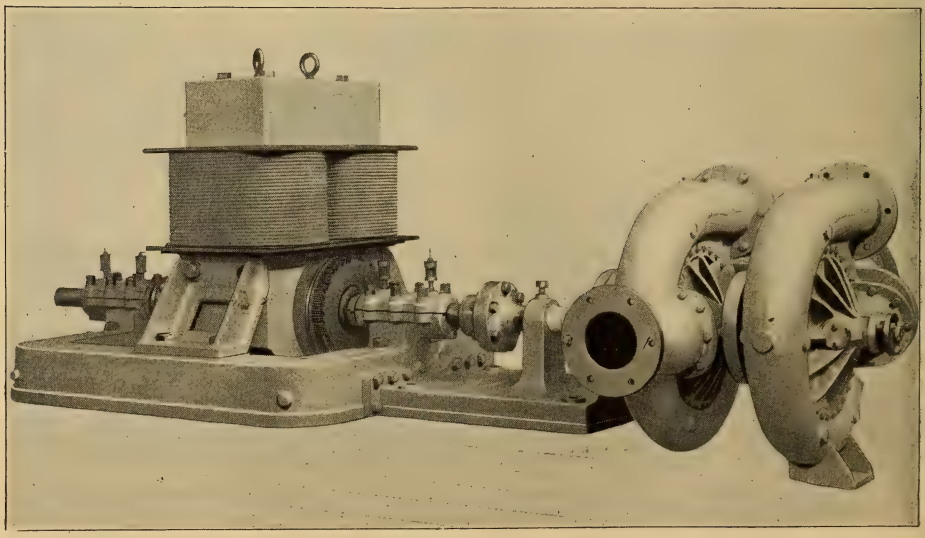
The dynamos should be located as near the mine as possible, preferably at the pit or shaft mouth. But of this subject more is told in another article in this issue.

The three-phase, alternating-current system is a more recent development, and constitutes one of the greatest achievements in modern mining engineering. The energy of an inaccessible water power converted into electrical energy by water-wheel-driven generators, and delivered to the transmission line at high voltage, may be transmitted economically through distances as great as seventy-five miles, and even farther under favourable commercial conditions. At the sub-station, located near the mines, the line voltage is reduced by means of step-down transformers to a comparatively low figure, at which the current is distributed to the various induction motors about the mines. If power be required for locomotive haulage, the alternating current may be transformed into direct current by a rotary converter which feeds into the trolley circuits in the usual way.

It is this possibility of ready transmission of comparatively cheap water power from a distance to the base of actual mining work and the consequent independence from coal, which is generally enormously expensive at mountainous mine locations, more or less inaccessible with the usual means of transportation, that have helped largely to make electricity a valuable ally to the miner. Sometimes, too, coal may be obtained at reasonable figures down in the valley, or twenty or thirty miles away at some favourably located spot, while at the working point, up the mountain side, its cost would be ruinous to profitable working. In that case it would be the relatively cheap coal power instead of water power that

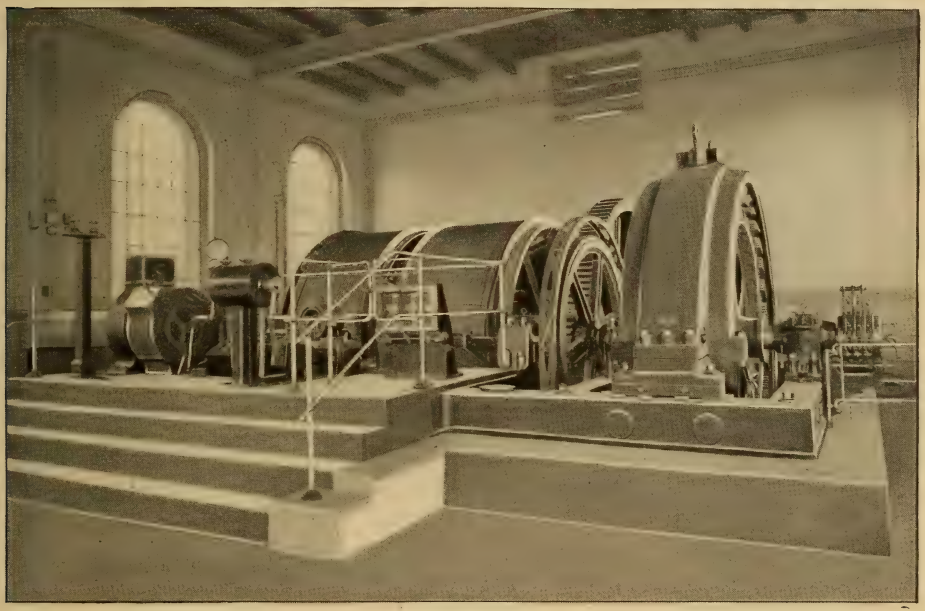


A TRIPLEX SINGLE-ACTING PORTABLE MINE PUMP, DRIVEN BY A GENERAL ELECTRIC COMPANY MOTOR



AN ELECTRIC DUPLEX CENTRIFUGAL PUMP OUTFIT, MADE BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE, ENGLAND. THIS MACHINE WAS USED FOR UNWATERING AN IRON ORE MINE IN THE CLEVELAND DISTRICT AND IS CAPABLE OF DELIVERING 1000 GALLONS PER MINUTE, AGAINST 150 FEET HEAD

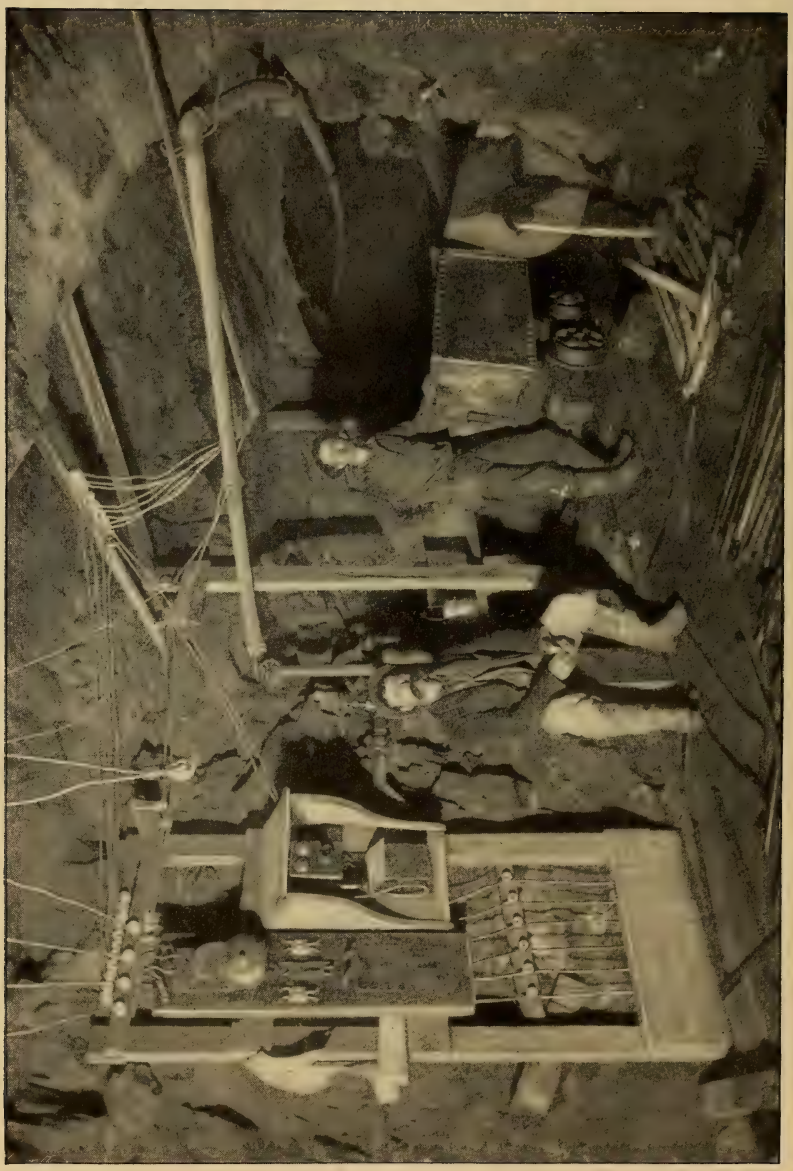
would be transmitted electrically. Or, even with cheap coal exactly on the spot, there might be scarce water supply for steam raising, and here, again, the electrical conversion and transmission of power at some more suitably located generating point would solve the power problem. In these several respects mining in the mountainous, western parts of the United States has furnished many striking examples,—more, in fact, than any other part of the world,—of electric power benefits. Electric drilling, hoisting, and hauling, electric driving, indeed, of all the moving machinery employed, has in those mines been a matter of vital necessity. It is the one thing that has made it possible to carry on the several enterprises at a profit.



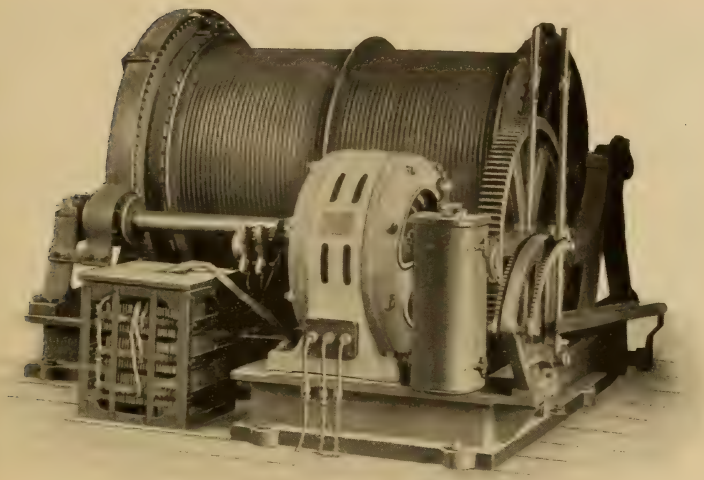
A 400 H. P. ELECTRIC MINE HOIST, INSTALLED BY THE SIEMENS & HALSKE AKTIEN-GESELLSCHAFT, VIENNA

It may not be uninteresting, therefore, to refer more specifically to several of these installations; to begin with, for example, to the one designed for the operation of the famous Comstock mines at Virginia City, Nevada. At a distance of thirty-three miles from the mines is located the power house of the Truckee River General Electrical Power Company, containing two 1000 H. P., three-phase, 500-volt alternating-current generators, direct connected, by means of flexible couplings, to turbines, each capable of developing 1400 H. P. under a working head of 85 feet. The voltage is raised by means of step-up transformers to 22,000 for the transmission line. The principal sub-station is located at Virginia City, where the voltage is reduced to 2200. The applications of electric power at these mines are being made on a very large scale.

Electric hoists will be used extensively, the largest using the balanced tail-rope system and being operated by 200 H. P. variable speed induction motors. Air compressors are belt-driven by large induction motors, and electric power will also be extensively used to operate the pumps eventually to displace the hydraulic elevators which have performed such excellent service in unwatering the mines. A 100-ton mill, with two sets of grinders and three sets of concentrators, has been equipped with



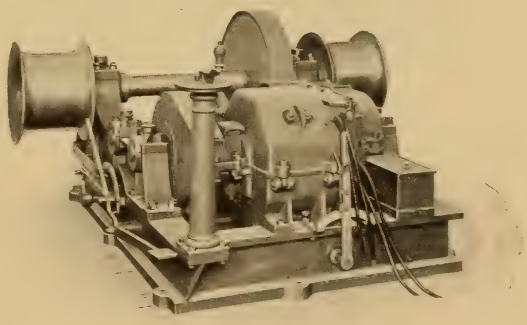
THE TELEPHONE IN MINE SERVICE. A STATION ON THE 2100-LEVEL, IN THE EMPIRE MINES, CALIFORNIA



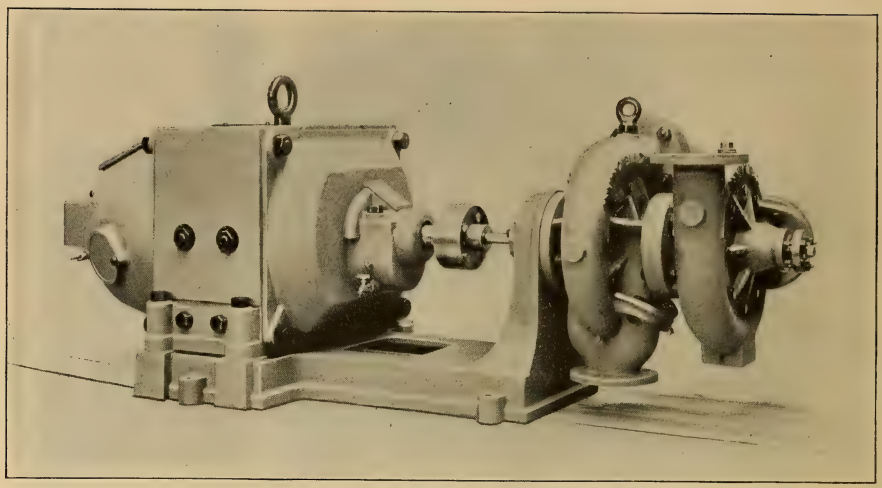
AN INDUCTION MOTOR, MADE BY THE BRITISH THOMSON-HOUSTON CO., LTD., LONDON, DRIVING A HOIST MADE BY THE LIDGERWOOD MFG. CO., NEW YORK AND LONDON

induction motors, and a small direct-current haulage plant is now in operation from a direct-current generator, belt-driven from an induction motor. In short, it is intended to operate the Comstock mines entirely by electric power.

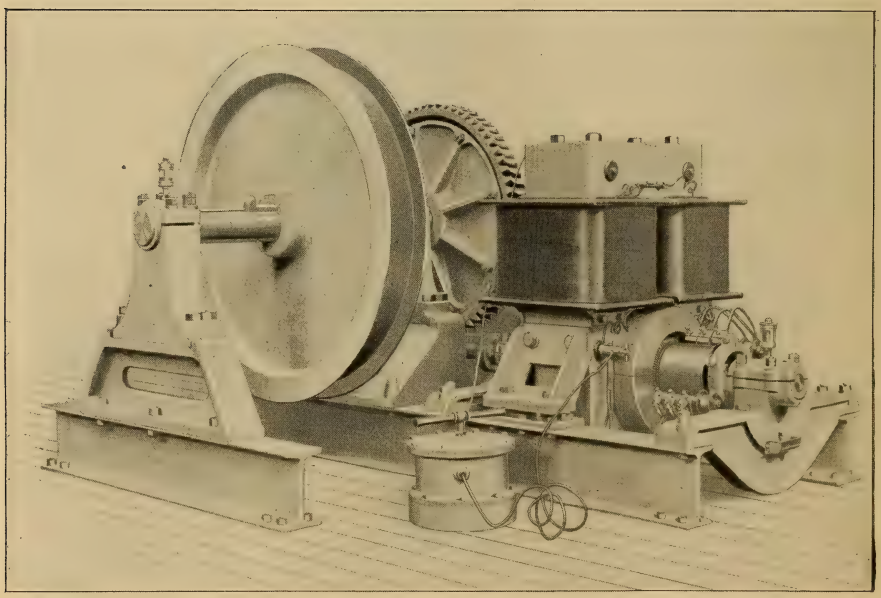
The water problem attained importance early in the history of these mines, and nearly twenty years have elapsed since the largest pumping plants were designed and installed. The subsequent completion of the Sutro tunnel and its employment for drainage changed the whole system of pumping as originally laid down. The costly and massive pumping engines were, however, allowed to remain on the surface, and the intervening pumps were relocated below the tunnel level and operated by long, heavy pump rods. The aggregate cost of the original pumping plants, exclusive of freight and installation costs, was about $1,500,000 (£300,000), and their total capacity was less than 5400 gallons per minute against a vertical head of 1150 feet,—nearly $1000 per water horse-power. The cost of operating for a period of six months, obtained from the books of the different companies, was $34.13 per month per indicated horse-power. To-day the rates of the Truckee River General Electrical Power Company vary from four to seven dollars per month per horse-power, depending upon the amount of power used and the resumption of operations in the Comstock Mines, which were shut



A DOUBLE WINCH WITH ELECTRIC MOTOR, HOISTING 2200 LBS. 300 FEET A MINUTE. BUILT BY THE BRITISH THOMSON-HOUSTON CO., LTD.



TWIN SERIES CENTRIFUGAL PUMPS DIRECTLY COUPLED TO AN ELECTRIC MOTOR FOR COLLIERY USE. MADE BY MESSRS. J. & H. GWYNNE, LTD., LONDON. DESIGNED TO LIFT 6000 GALLONS OF WATER PER HOUR TO A HEIGHT OF 100 FEET



AN ELECTRICALLY-DRIVEN ENDLESS ROPE HAULAGE GEAR, MADE BY MESSRS. ERNEST SCOTT & MOUNTAIN, LTD., NEWCASTLE-ON-TYNE, ENGLAND

down for several years, was due entirely to this cheap electric power.

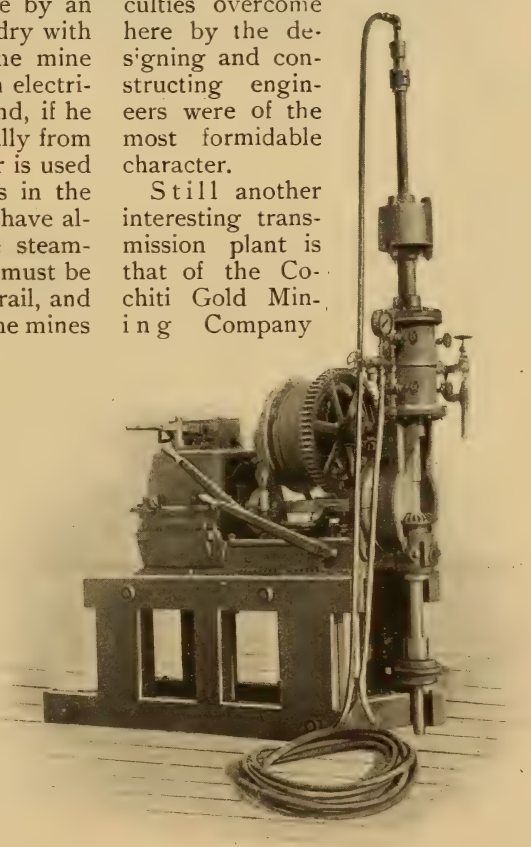
Another interesting installation is that of the Colorado Electric Power Company, at Cañon City, Colorado, the power house being located in close proximity to one of the coal mines of the Cañon City coal field. This plant consists of large engine-driven alternators, aggregating 2000 H. P. and generating multiphase current at 500 volts. By means of step-up transformers the

voltage is raised to 20,000, at which the current is transmitted to the Cripple Creek mining district, twenty-seven miles distant, where the voltage is reduced to 500 and the power distributed to the various mines for the operation of hoists, pumps, crushers, concentrators, air compressors, blowers, and other machinery. This company has adopted the unique plan of leasing the electric hoists as well as furnishing power for their operation, and about seventy-five hoists are now operated in this manner. This arrangement enables the prospector to invest his entire capital in development work and avoid the necessity of purchasing and installing a power plant.

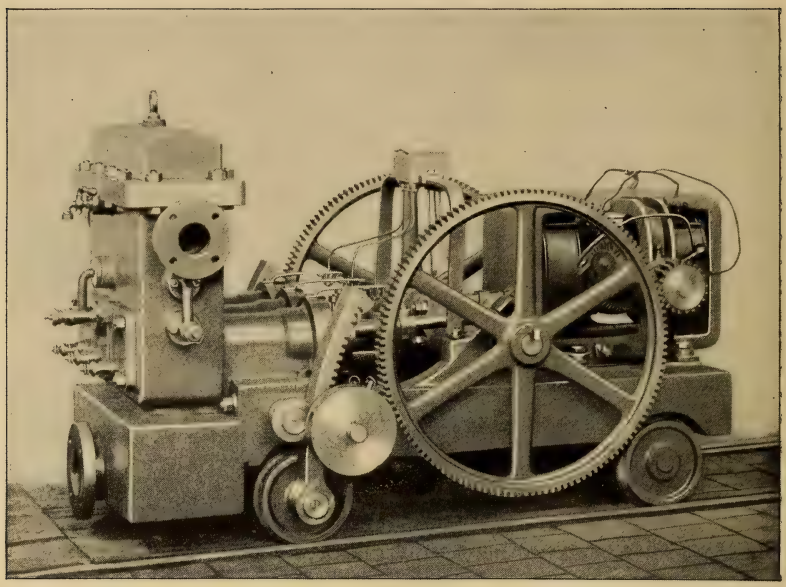
Cripple Creek is, perhaps, the only mining district in the world where the miner may go to his work in an electric tramcar, descend into the mine by an electric hoist, keep the mine dry with an electric pump, illuminate the mine electrically, operate drills from electrically-driven air compressors, and, if he chooses, fire his blasts electrically from a safe distance. Electric power is used extensively in new installations in the district, and induction motors have already displaced several of the steam-engines formerly in use. Coal must be transported from a distance by rail, and finally up the steep hillside to the mines by teams, costing from $6 per ton up, principally up. Located at a great altitude, the camp is dry (literally, not metaphorically), and in many steam plants water has also to be carted to the boilers, costing as much as the fuel. On account of the altitude considerable trouble is experienced, due to freezing of the water, and delays on this account are frequent during the winter months. Under such circumstances it is easy to understand the extensive use of electricity and to conclude that the same results could be accomplished in no other way.

The Cripple Creek district is also supplied with power by the La Bella Mill, Water, & Power Company, whose plant is located at Goldfield, and by the Pike's Peak Power Company. The La Bella plant contains three 750 KW, three-phase alternators, direct-connected to 1000 H. P. steam-engines, and is one of the most complete and modern electric power plants in the world. The Pike's Peak Company's plant is operated by water power, and the power house is located about eight miles from Victor, Col., where the Gold Coin mine forms the centre of distribution. The electrical equipment consists of four 400 KW, three-phase alternators, direct-connected to Pelton impulse wheels running under an effective head of 1160 feet. The natural difficulties overcome here by the designing and constructing engineers were of the most formidable character.

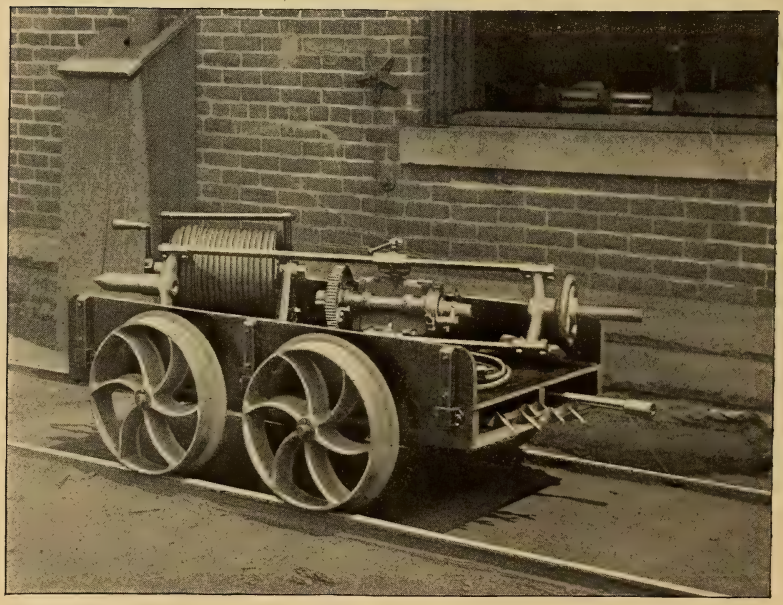
Still another interesting transmission plant is that of the Cochiti Gold Mining Company



A CORE DRILL, ELECTRICALLY DRIVEN, MADE BY THE SULLIVAN MACHINERY CO., CHICAGO



AN ELECTRIC PORTABLE TRIPLEX MINE PUMP, MADE BY THE BRITISH SCHUCKERT ELECTRIC CO., LTD., LONDON

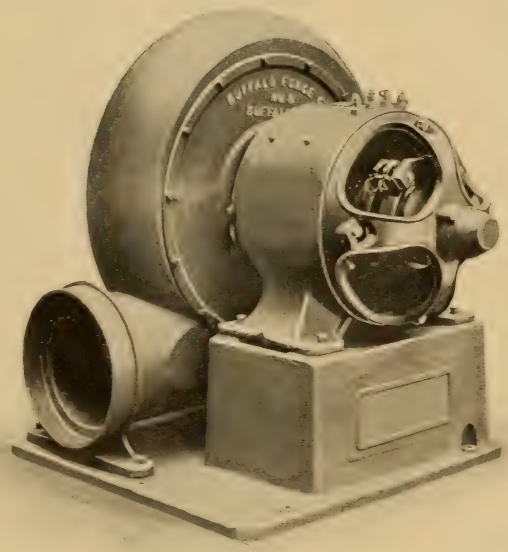


AN ELECTRIC DRILL WITH TRUCK, CABLE, AND SET OF AUGERS AS SUPPLIED TO COAL COMPANIES BY THE GENERAL ELECTRIC CO., SCHENECTADY, NEW YORK

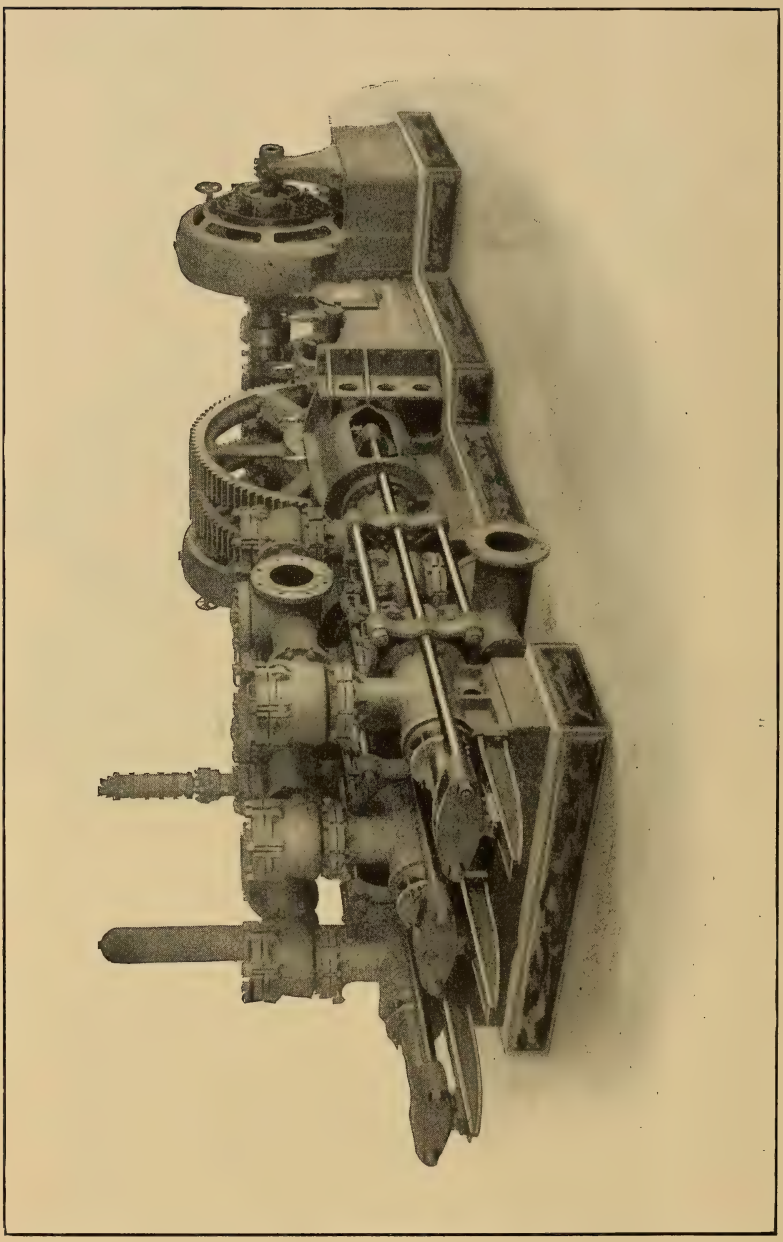
The power plant is located near the coal mines of the Colorado Fuel & Iron Company, at Madrid, New Mexico, and the power is transmitted at 20,000 volts to the mines and mills at Albemarle, thirty-two miles distant. The power house contains a three phase, 600 KW alternator, direct-connected to a steam-engine, and the addition of a duplicate unit in the near future is contemplated. The coal crusher and the coal and ash conveyors in the power house are each operated by a 10 H. P. induction motor. Water for the boilers is obtained from the Galisteo River, 14,000 feet distant, and is handled by one deep-well pump and two triplex force pumps, each operated by a 10 H. P. induction motor. The motor equipment at Albemarle consists of three 150-H. P. induction motors driving the mill and air compressor, one 100-H. P. induction motor on a double drum hoist, for raising the ore in the main shaft, together with smaller motors aggregating 80 H. P. for various purposes around the mill and machine shop. The transmission line is constructed over a very mountainous country, but very little trouble has been experienced with it. A line rider is employed, who goes over the line on horseback every other day, thus avoiding any serious trouble from washouts, broken insulators, and other mishaps.

For the operation of the old steam plant at Albemarle wood cost from $4 to $5 per cord, and coal would have had to be carted twenty-five miles over a very rough country from the nearest railway. The cost of operating the old steam plant with wood as fuel, when hoisting and milling 200 tons of ore per twenty-four-hour day, amounted to $218. The present plant, with coal as fuel, consumed at a distance of thirty-two miles, handles 300 tons of ore per day, and the cost of operation is $53,—indeed, a striking comparison.

The induction or alternating-current motor possesses important advantages over the direct-current motor, so that in many plants, even where there is no long-distance transmission, the alternating current is preferable. The only really undesirable feature of the direct-current motor is the commutator, by means of which the current is delivered to the armature windings. To ensure successful and satisfactory operation it is necessary that the commutator receive considerable care. The characteristic feature of the induction motor is the absence of the commutator, in fact, in almost all types of induction motors, the entire absence of moving contacts of any kind. The electrical energy is delivered to the field winding, and the rotative effect is due to magnetic induction, which causes currents to flow in the rotating member or armature, these, in turn, reacting upon the currents in the field. Sometimes the armatures are provided with collector rings for speed regulation, but they are by no means analagous to the



AN ELECTRICALLY-DRIVEN FAN FOR MINE VENTILATION, MADE BY THE BUFFALO FORGE CO., BUFFALO, NEW YORK



A TRIPLEX DOUBLE-ACTING MINE PUMP, BUILT BY THE JEANESVILLE IRON WORKS CO., JEANESVILLE, PA. DESIGNED FOR LARGE VOLUME AGAINST LIFTS UP TO 1500 FEET. DRIVEN BY A GENERAL ELECTRIC COMPANY MOTOR

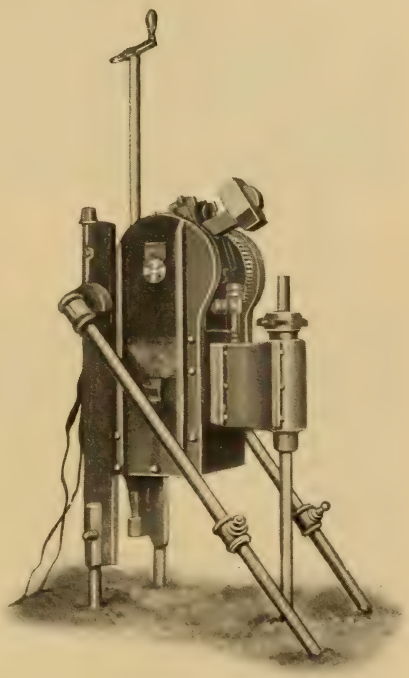
commutator of the direct-current motor.

The maintenance of the induction motor costs less than that of the direct-current machine on account of the extreme simplicity of the former. As already stated, direct current may be considered essential for locomotive haulage, and is perfectly satisfactory if the other uses of electric power are not numerous. If, however, there are pumps to be driven electrically, and fans, conveyors, and other machinery, it would be advisable to install at the power house generators of both kinds, a direct-current machine for the haulage, and an alternator for the various motors.

One of the earliest applications of electricity to mining was the electric mine locomotive. The first electric mine locomotive in the United States was built in 1887 for the Lykens Valley Colliery of the Pennsylvania Railroad Company, and was, under the circumstances, a remarkable success. At that time there were in Germany two similar installations, at Zankerode and Hohenzollern, to one of which probably belongs the distinction of being the first electric mine locomotive haulage plant in the world. This subject is a broad and an interesting one in itself, and, as already stated, is comprehensively treated in an article elsewhere in this issue.

Pumping is naturally one of the most important problems encountered in mining, and in its solution the electric motor is extensively used. It must be admitted that there is little advantage in the electrical operation of very large pumps, unless, as is often the case, their location in the mine makes the use of steam pipes undesirable, or unless cheap power can be obtained from a distance by means of the electrical transmission system. Large steam pumps compare very favourably in efficiency with the type of engines used for driving electric generators.

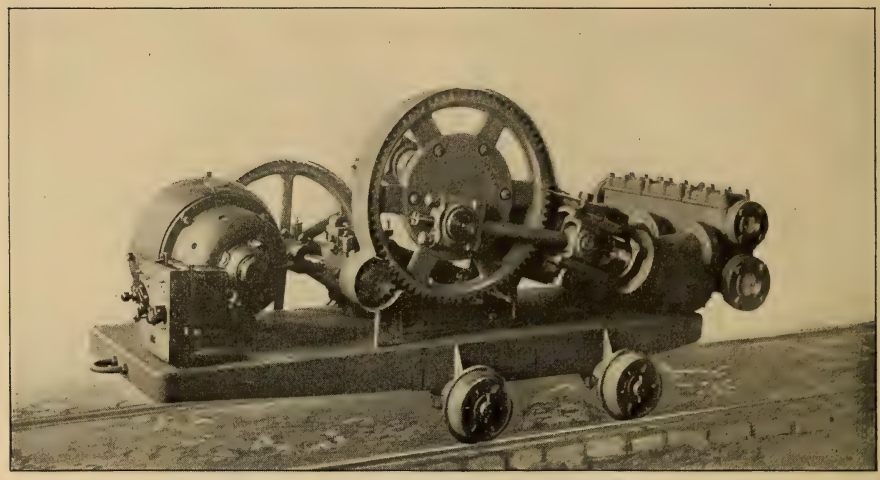
Economy, however, is by no means an attribute of small pumps, many consuming as high as 120 pounds of steam per H. P. per hour, and under the conditions ordinarily encountered in mining there is no doubt of the superiority of the electric pump. For electric driving the pump itself embodies no special features, and may be horizontal or vertical, or of the piston or the plunger type, whichever may be most suitable for the conditions. In general, however, it is advisable to use a double-acting pump, either a duplex or triplex. To raise a certain amount of water against a certain head, a definite amount of power is required; but if distributed between



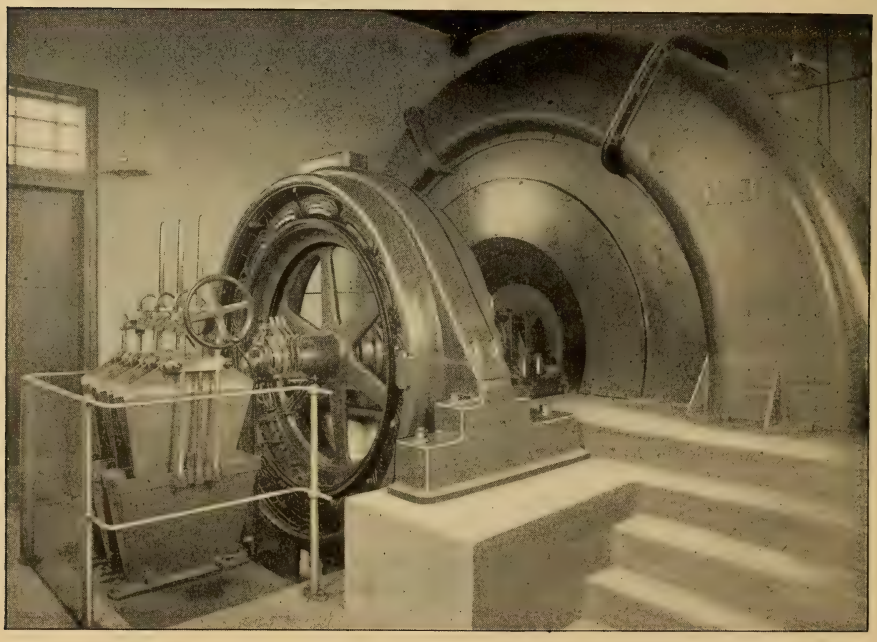
A PORTABLE ROCK DRILL, OPERATED BY ELECTRIC HAMMER BLOWS

two or three double-acting cylinders there will be a more uniform flow of water and the strains on motors and pumps will be reduced; in fact, a motor driving a triplex double-acting pump may be smaller than a motor operating a simplex single-acting pump, performing the same duty.

The speed of the electric motor is such that double-reduction gearing is usually necessary. The writer desires to emphasise at this point the desirability of using motors of as low speed as



TRIPLEX PORTABLE MINE PUMP, ELECTRICALLY DRIVEN, MADE BY THE DEMING COMPANY, SALEM, OHIO, U. S. A.



A MINE VENTILATING FAN DRIVEN BY AN ELECTRIC MOTOR. INSTALLED BY THE SIEMENS & HALSKE ATKIEN-GESELLSCHAFT, VIENNA, AUSTRIA

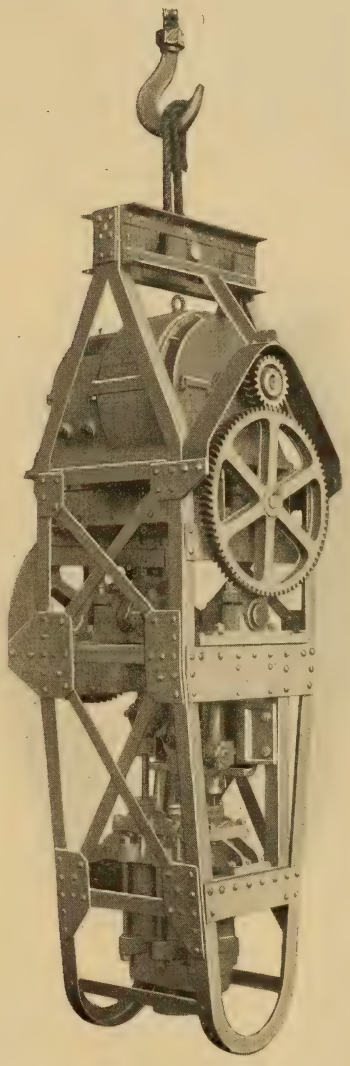
possible, not to eliminate the gear reductions, but to reduce the gear speeds to the minimum. The troublesome results of high gear speeds are too well known to need any discussion.

An important attribute of the electric pump is its portability. In many mines the pumps are mounted on trucks and are regularly moved from one sump to another. A stationary electric pump may be controlled from a distance, or arranged so that it will automatically start when the water in the sump reaches a certain level and stop when the water level is reduced to the desired point. In this way the pump may operate without attention, say, ten hours a day intermittently, and, in an emergency, perform double duty by continuous operation.

In connection with development work, the electric sinking pump is efficient and convenient. This style of pump is very compact, and as it may be completely submerged, it does not have to be relocated as often as a steam pump. It is, of course, practically undesirable to submerge a steam sinking pump on account of the condensation of the steam which would result in the cylinder and steam pipe. The electric sinking pump may, moreover, be lowered from one location to another in much less time than a steam or compressd air pump, —a feature of importance in a shaft that is making water rapidly.

For pumping against low heads and for handling muddy water the centrifugal pump has become very popular. Its efficiency, when working against the proper head, compares very favourably with the efficiency of a reciprocating pump, while the initial cost is much less. One manufacturer has recently placed upon the market a special pump of this type designed for the relatively high heads of 100 to 200 feet. The same results have been accomplished by compounding ordinary centrifugal pumps, that is, placing two or three on the same shaft and operating them in series, so to speak.

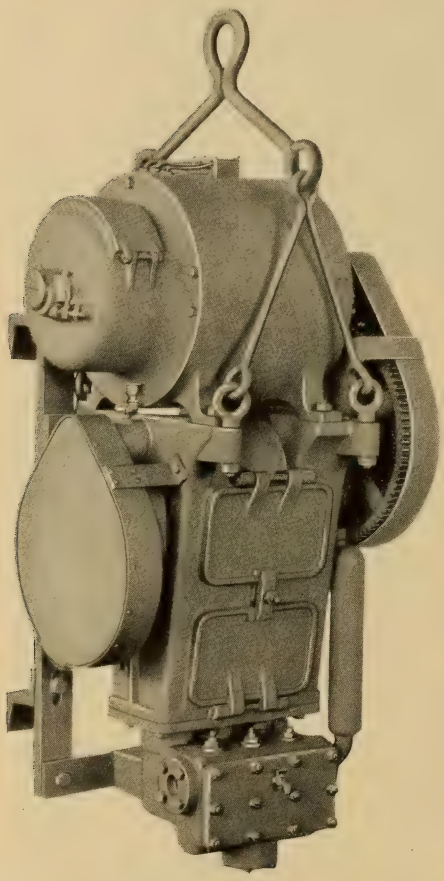
On account of its rotary motion and high speed the centrifugal pump is especially suitable for electrical operation, and the pump and motor are usually direct-connected. The principal objection to the centrifugal pump is the necessity of priming, but this may be overcome by using a foot valve of proper design, or, as is often done, by completely submerging the pump and operating it by a special motor with a vertical shaft, or by an ordinary motor through mitre gearing.



AN ELECTRICALLY-DRIVEN THREE-THROW SINKING PUMP. MADE BY MESSRS. EASTON & CO., LTD., ERITH, KENT, ENGLAND

The electric hoist is one of the most

important of the many applications of electricity in mining and is used for a variety of purposes. A typical electric hoist consists of an electric motor driving the drum proper through double-reduction gearing. The drum is usually controlled by a friction clutch and a powerful band brake. The series-wound, direct-current motor is especi-



ANOTHER TYPE OF ELECTRIC SINKING PUMP

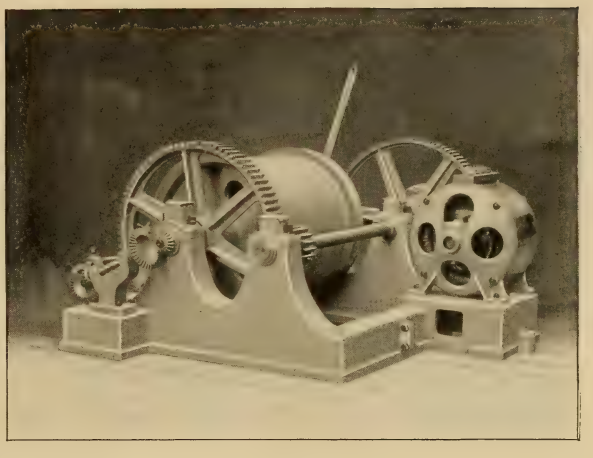
ally suitable for the operation of electric hoists on account of its great starting torque and rapid acceleration. The alternating-current induction motor, with definite wound armature, collector rings and external resistance, is also capable of speed variation, and is very extensively used for this purpose. In hoisting, strictly speaking, little can be gained by very high speeds unless the shaft is of great depth. The higher the speed, the greater the time consumed in acceleration and the less in actual running at full speed. If a very high speed be attempted, acceleration will hardly be accomplished before the cage reaches the surface.

In many mines the main shafts are operated by electric hoists with most excellent results. The electric motor has also been successfully applied to the operation of tail rope systems, engine planes, and car hoists at coal mine tipples. The electric motor may be further applied to the endless rope-haulage system, and is especially suitable for the operation of the tributary ropes, usually driven from the main ropes and consequently in constant motion. It is unnecessary, however, for a tributary rope to operate continuously, and it should, therefore, be driven by a separate electric motor and driven only when actually hauling cars to and from the main rope.

Gold dredges of the continuous-bucket type have been operated successfully for a number of years in the rivers of New Zealand, and, to a certain extent, in Australia, and a large number of them have been built and equipped with electric moters for service in California, the motor equipment being made up about as follows:—One 50-H. P. variable-speed induction motor for driving the main bucket chain; one 50-H. P. constant speed induction motor, direct-connected to two centrifugal pumps; one 20-H. P. constant-speed induction motor for driving the revolving screen and the tailings elevator; one 20-H. P. induction motor for driving the sand pump; one 10-H. P. induction motor, variable speed, for driving the winches for the side and head lines; and one 10 H. P. variable-speed motor for lowering the bucket ladder.

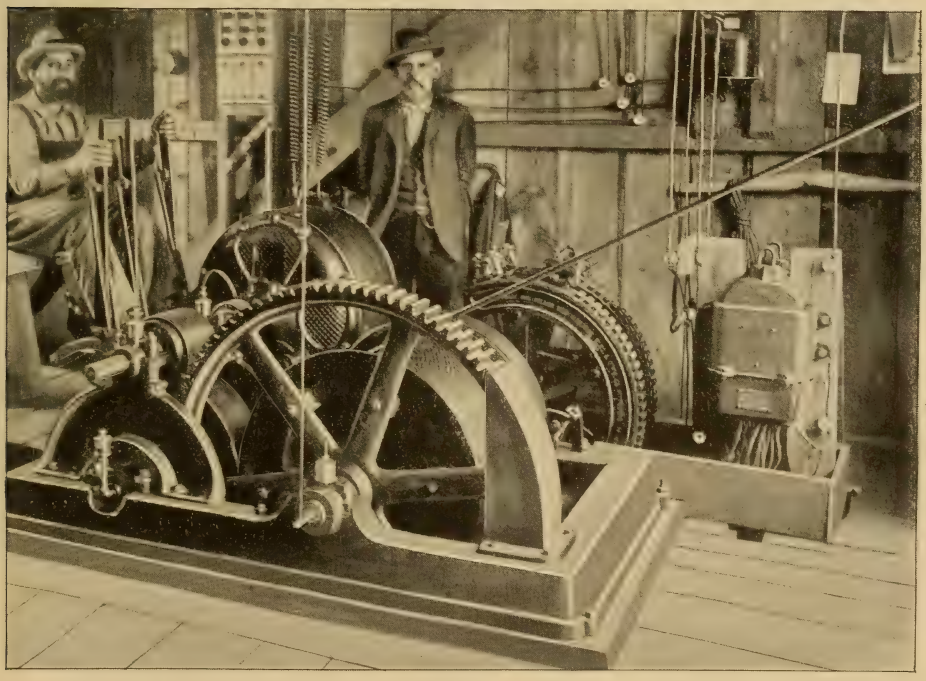
Another application of electric power driving has been made in connection with coal cutting machinery. Of this, however, extended mention is made in the special article on that subject by Mr. E. W. Parker in another part of this issue.

The design of a satisfactory electric rock drill has been the aim of many engineers, and much money has been spent in the fruitless effort to accomplish that result. An electric solenoid drill was placed on the market several years ago, but the drill, although theoretically very attractive, was hardly practical, and never enjoyed extensive use. Until a comparatively recent date no electric drill has been built which compared favourably with the compressed air drill. These remarks, by the way, apply also in general to coal-cutters of the "puncher" type.

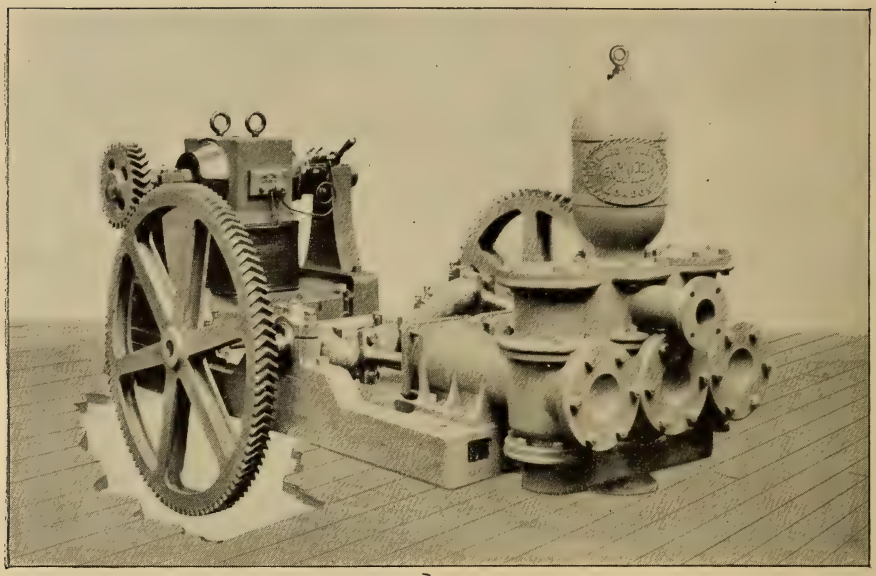


AN ELECTRIC HOIST MADE BY MESSRS. GANZ & CO., BUDA-PESTH

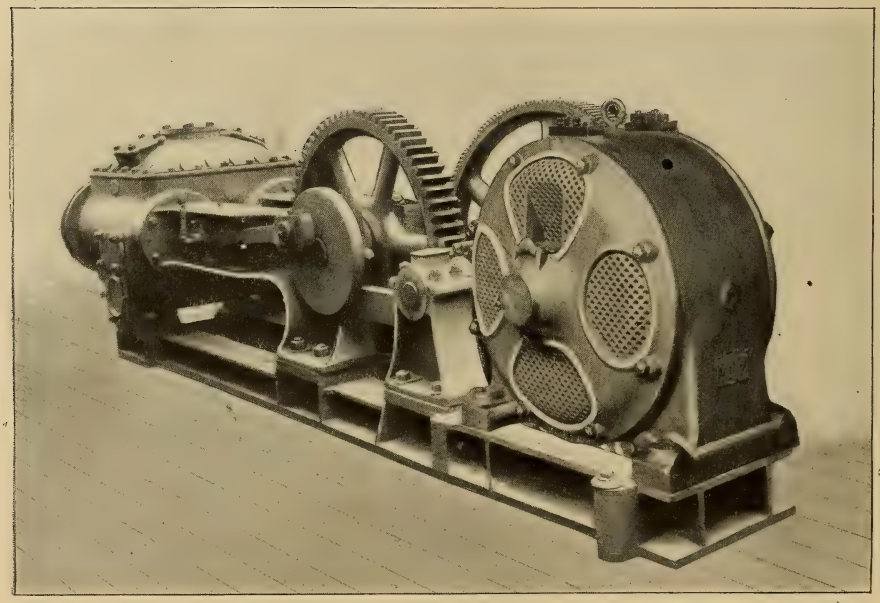
One form of electric drill recently brought out in the United States, and promising to become an active competitor to the compressed air drill, is shown on page 409. It belongs to the percussion class, the power being transmitted from the electric motor to the drill by a flexible shaft, usually about 8 feet long. A similar drill has been used in Germany for some time, and the indications seem to point to the extensive use of this type of drill in this country. Another interesting electric drill, also a recent development, is illustrated on



A WESTINGHOUSE ELECTRIC HOIST IN A CRIPPLE CREEK, COL., MINE



AN ELECTRIC MINE PUMP BUILT BY MESSRS. HAYWARD-TYLER & CO., LONDON



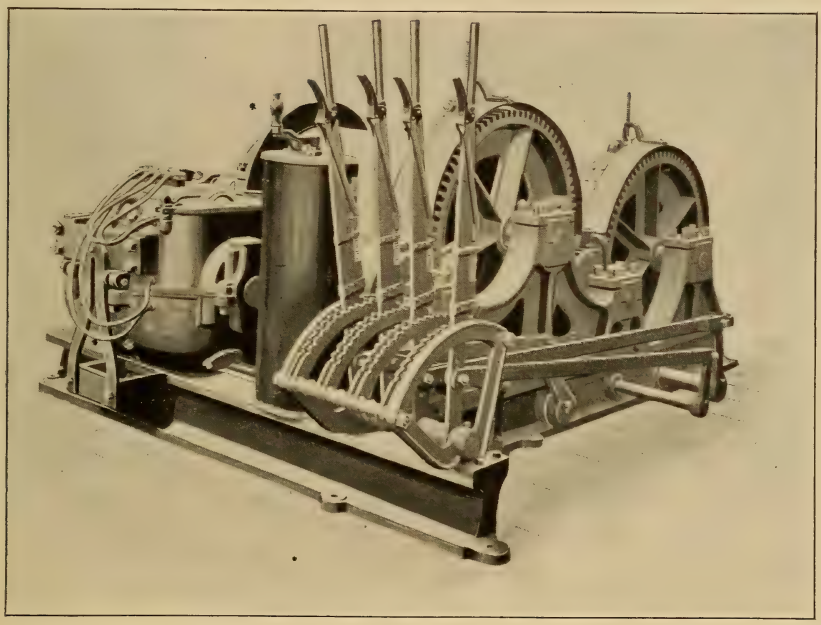
PUMP DRIVEN BY AN ALTERNATING CURRENT MOTOR, MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURGH AND LONDON

page 421. This drill is operated by a self-contained electric motor, and is, in short, an automaton, striking between four and five hundred powerful hammer blows per minute. The hammer proper is operated by a pair of eccentrics on a shaft, driven through single gearing by the armature of the motor. The raising of the hammer is effected during a three-quarter revolution of the eccentric shaft, while the blow is struck during the remaining quarter, thus obtaining a very powerful and effective blow.

In coal mining, electric rotary drills or augers are quite common, and are used for drilling holes in the coal for shooting it down after it has been undercut. The drill is usually mounted on a light upright with screws at the ends for fastening to the roof and floor. The motor, which is very small and light, is mounted on adjustable clamp and drives the auger through a single-gear reduction. The rapidity with which these drills enter the coal is astonishing.

In several mines operated by electric power the prospecting is accomplished with electrically-driven diamond drills. The electric diamond drill, however, will never be extensively used, as electric power is not ordinarily available in prospecting of a preliminary nature. In the underground prospecting of a large mine the electric drill is very convenient, as it can be set up and moved about with great facility.

Ventilation is an important problem in all mines of any considerable size.



AN ELECTRICALLY-OPERATED HOIST BUILT BY THE S. FLORY MFG. CO., BANGOR, PA., U. S. A.

In several collieries the main fans are driven electrically, while in tunnel work the small electric blower is most useful for rapidly clearing away the smoke after a blast and keeping the air at the face fresh and pure. The larger fans are usually belt-driven on account of their very low speeds, while of the smaller sizes the speeds are comparatively high and motor and fan are direct-connected, forming a compact unit.

The advantage of the electric firing of explosives, from the standpoint of accuracy and security, is shown in the experience of German collieries, as recorded in an official report. In one colliery no misfire occurred out of 1663

shots fired; in five other collieries there were 548 misfires out of a total of 34,207 shots, a proportion of 1.6 per cent.

An interesting application of the telephone has been made in one coal mine where an electric pump is located in a worked-out portion of the mine and the circuits are so arranged for the sake of convenience that the pump is started from the power house. The telephone transmitter is placed near the pump and connected to a receiver in the power house. When starting the motor, and occasionally while the pump is in operation, the engineer listens at the telephone receiver and easily ascertains whether or not the pump is operating properly.

As this paper is supposed to deal with electricity in mining, it is hardly within its scope to consider the uses of electricity in metallurgy. The latter industry is so closely allied to mining, however, that it may not be out of place to state that electricity is used very extensively in the various branches of metallurgy. One of its most interesting applications is in the electrolytic refining of copper, practically all commercial copper being now refined in this way.

With all the various applications of electricity in mining work, however, it is in the utilisation of available water powers that the most important developments may be expected. An installation is now being made in India which will be closely watched by mining and electrical engineers. The government of the State of Mysore has contracted to supply the mines and mills of the Colar gold field with motive power transmitted electrically more than ninety miles from the Cauvery Falls, a magnificent water power. Fuel is very expensive in the Colar region, and, furthermore, the introduction of electric power will naturally reduce the amount of unskilled native labour, which, at the best, is very poor, even considering the low wages. The Mysore Government is erecting the entire plant, from waterwheels to motors, including even the necessary alterations in the existing plants, without contribution from the mines, but it is understood that a moderate rental will be paid in addition to the power charges, the contracts being made for a period of ten years. The introduction of electric power will effect substantial economy without additional investment on the part of the consumer.

In the gas engine, too, we have a potent factor towards extending the use of electricity in mining. With cheap gas, made from cheap coal waste in the coal regions, this type of engine, in combination with an electric generator, forms an excellent and a flexible power system, and seems destined to undergo a noteworthy development in the near future.

WATER POWER IN MINING

ITS VARIOUS APPLICATIONS IN THE UNITED STATES

By A. P. Brayton

THE successful working of nearly all mining properties is confronted at the outset by the question of power. Even in prospecting work it is usually necessary to drive a hoist and a mill of some kind, and not infrequently, when confidence in the property has been established, a power plant that will serve later for actual working on a larger scale is considered a good investment by the owners.

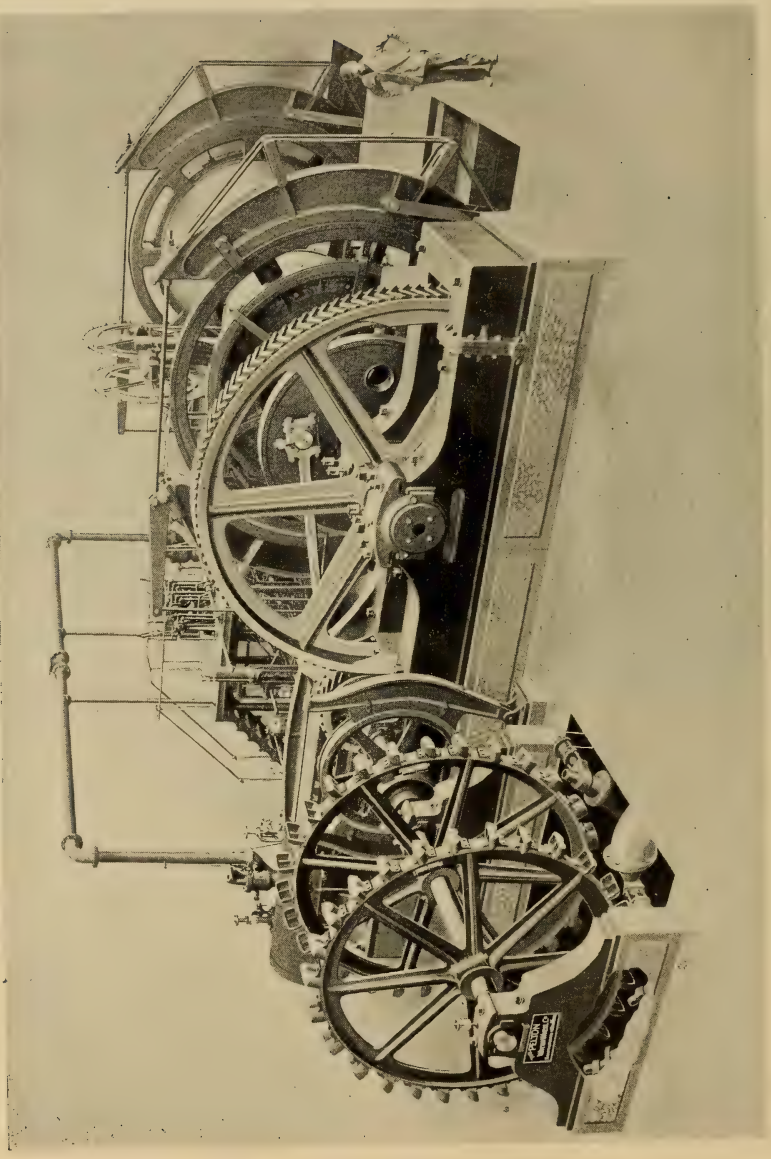
As the mine is developed, the amount of power required increases very rapidly. Ventilating and drilling call for air compressors; deep shafts require larger hoists and a considerable increase in the rope speed; keeping the mine properly drained at the lower levels necessitates large pumps; and, if the mill be located at some distance from the shaft, it becomes necessary to carry quantities of the ore over considerable distances by suitable tramways.

The breaking-down of any of the machinery involved in the various operations almost invariably necessitates the suspension of all other operations, and is frequently accompanied by the enforced idleness of much of the labour. This greatly increases the monetary loss due to the large investment lying idle, and the telegraph wires must be kept hot ordering new parts from long distances to be shipped by express, and this at large cost to the stockholders. Indeed, many mines that, properly engineered, would have proved good investments, have swamped their owners in an expense account beyond all reason on account of the burden of inefficient or badly operated power plants. The very best machinery is much the cheapest where the dividends are largely dependent upon continuous operation.

The sub-division of all of the power employed about a mine into small units,—one here for a compressor, two more, several thousand feet away, at the shaft, for the hoist and Cornish pump, and a mill down in the valley,—demands that the question of power be very carefully considered as a most important element in the mine economy.

Water power, when obtainable, offers a most satisfactory solution of the problem for many reasons. Mining properties are usually in the more inaccessible regions, removed from the beaten paths of travel, and the expense of fuel transportation, therefore, adds very greatly to its primary cost. It is not unusual to find mines where coal costs from twelve to fifteen dollars (£2.8.0 to £3) per ton, and that within a few miles of a terminal where it can be bought for about half that amount.

In the mountainous districts of the United States wood is frequently available for fuel; but at best this does not last for any great period of time, and the expense of cutting and hauling is very considerable. Many of the older mines are now surrounded by barren wastes. More particularly is this the case in Mexico, Central and South

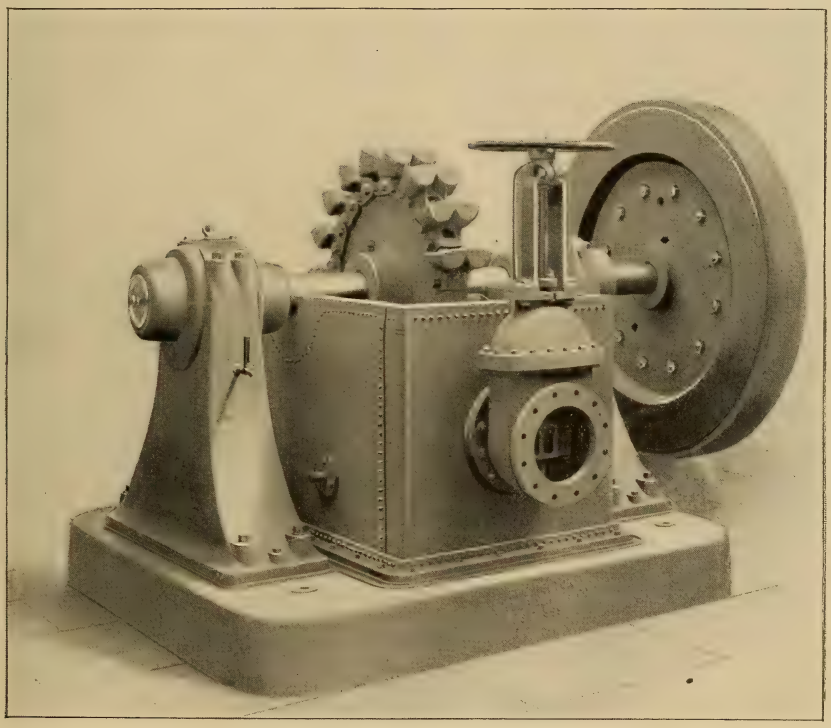


A DOUBLE-DRUM HOIST OPERATED BY EITHER STEAM POWER OR PELTON WATER-WHEELS

America, where, if wood ever existed in appreciable quantities, it has been almost entirely used up. It has, therefore, become necessary to import coal or develop water powers, almost regardless of first cost. If coal or wood has to be purchased the cost will often run well above $250, or about £50, per horse-power per year, and consequently a very considerable expense in the development of a water power is entirely admissible, a well-developed power very greatly increasing the value of the mine.

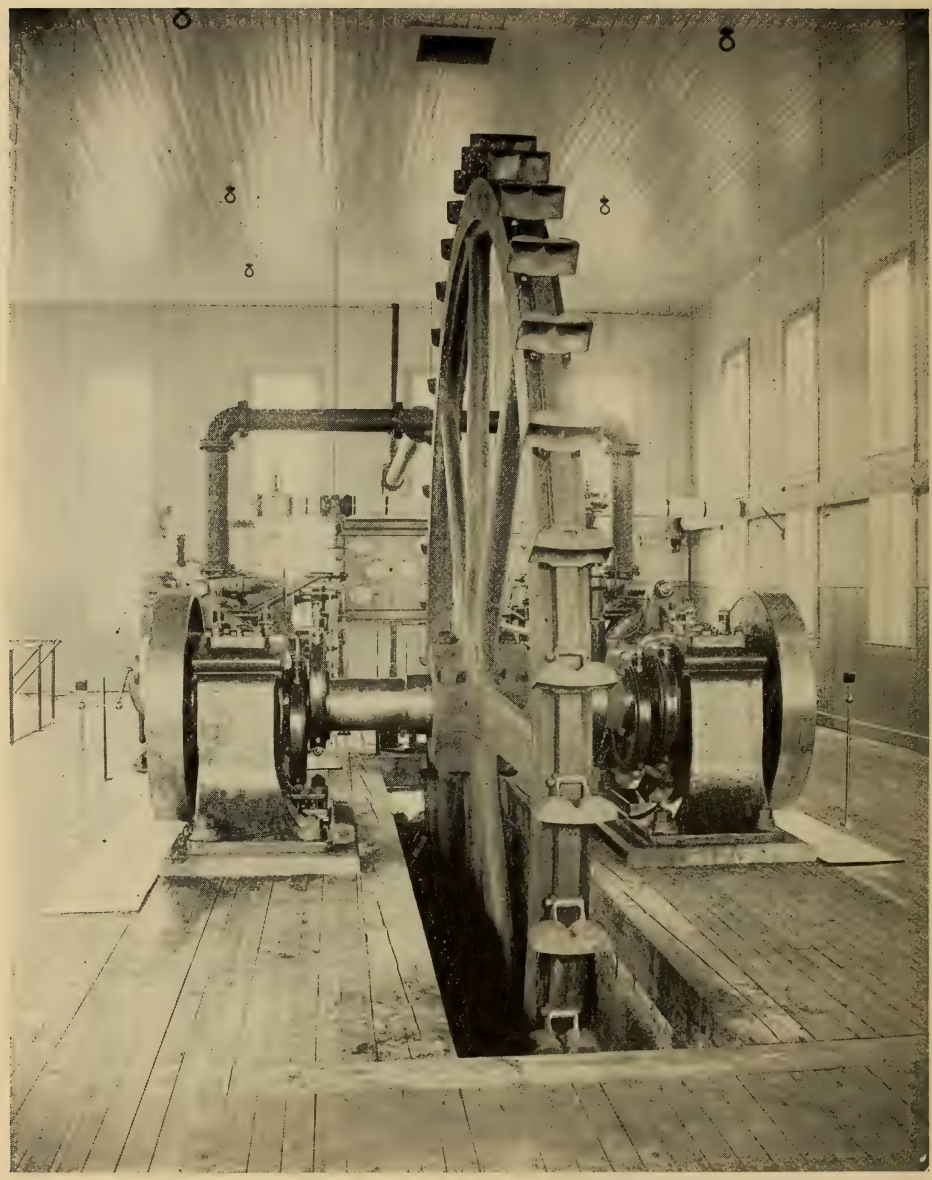
If a sufficient quantity of water can be obtained at a good pressure, it can usually be piped to the various points where power is required, and individual water-wheels can be adapted to the different machinery. If this is not feasible, one plant can be installed and power transmitted electrically to suitably arranged motors at the several points where required.

In no other part of the world is water power for mining purposes so frequently met with, or used to such an extent, as on the slopes of the Sierra Nevada range of mountains on the Pacific coast of the United States, extending over a distance of 1200 miles from Mexico to British Columbia, and including an extremely rich mineral belt. The western slopes of this range provide an enormous water-shed for the annual rainfall, besides a very heavy fall of snow in the more northerly sections. This, by the slow process of melting, keeps the innumerable streams well supplied until late in the summer,—long after the supply from the winter rains has found its way to the sea.



A FIVE-FOOT WHEEL FOR DIRECT CONNECTION TO A 750 KW ELECTRIC GENERATOR

As early as 1853 a system of ditches was inaugurated in that region, taking water from some of the streams of constant flow near their source in the upper Sierras, and carrying it down to the foothills by means of wooden flumes or earth canals along the divides. Some



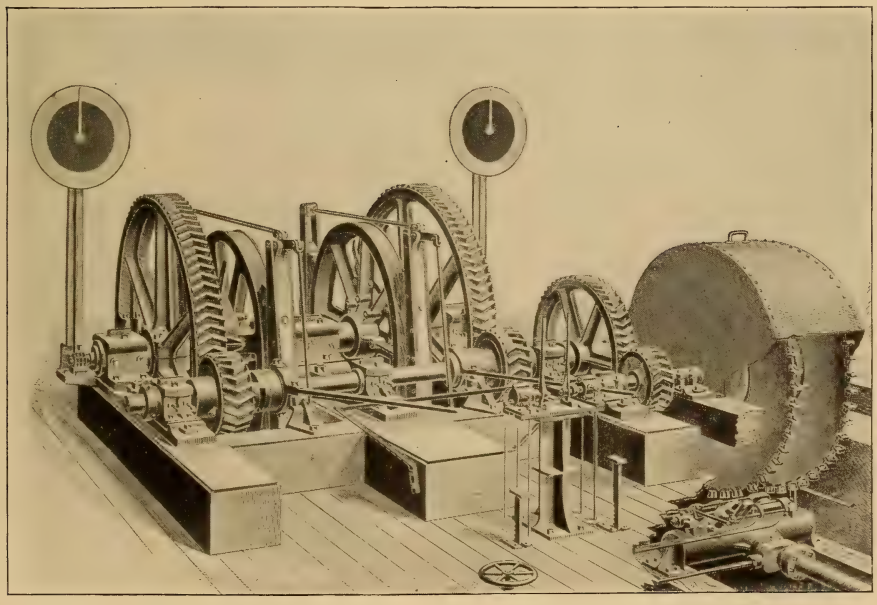
A COMBINED STEAM AND WATER POWER COMPOUND AIR COMPRESSOR WITH A 22-FOOT PELTON WHEEL AT THE TREADWELL MINE, AT DOUGLAS ISLAND, ALASKA

of these ditches are more than 100 miles long, and carry several thousand miner's inches. The miner's inch is a California unit of measurement, varying with the different ditch companies, and is equal to from 1.2 to 1.8 cubic foot per minute. This process of ditching and fluming has been going on ever since, until now there are few mining localities on the Pacific coast where water by this means under considerable pressures is not available for mining purposes. The existence of these ditches, even in the field of the railroads, is proof that the water can be sold at a remunerative rate for power in competition with coal and

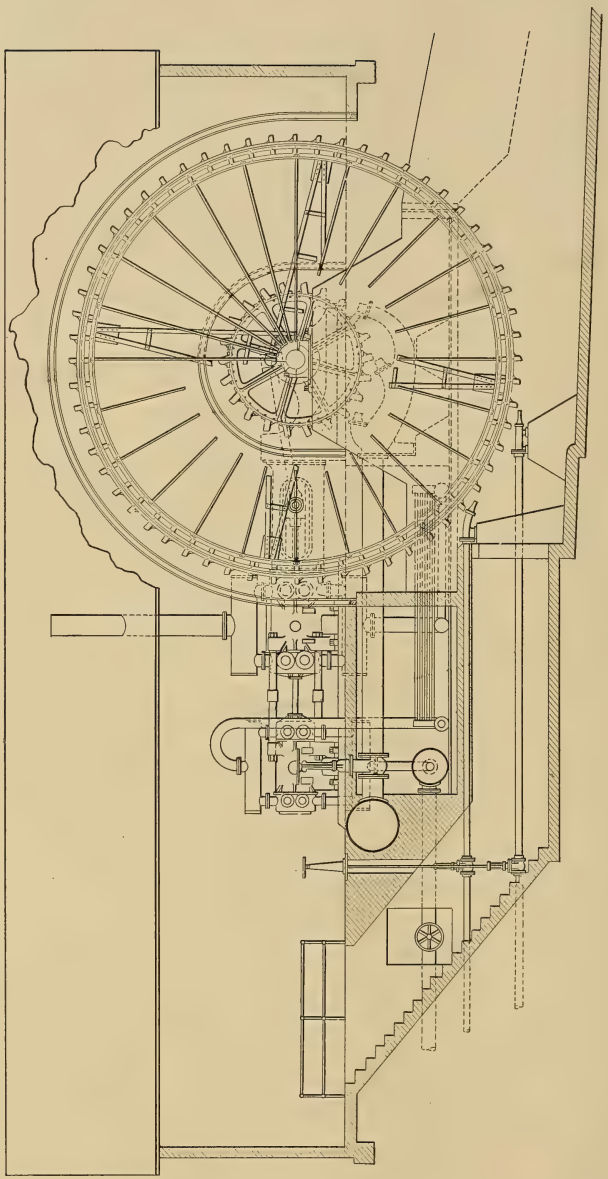
wood. The development of mining in California has carried with it the evolution of the tangential water-wheel from the earliest comparatively crude hurdy-gurdy wheel to the modern highly efficient and reliable form now in almost universal use. One is impressed with the great scarcity in California of all forms of turbine wheels, probably because of the almost total absence of conditions suitable to their successful operation. The speeds are usually too high to admit of direct connection to the machinery to be driven, and coupled with this fact are the great expense involved in the frequent repairs necessary and the usual absence of skilled labour. The tangential form of wheel is, therefore, preferable in most instances.

The tangential water-wheel is one which revolves freely in the air and receives the impact of one or more water jets in suitably shaped buckets, arranged symmetrically around its periphery. The streams of most mining districts carry large quantities of quartz tailings, which cut out the running parts of a turbine with great rapidity, reducing its efficiency and length of life. This sand-blast effect, however, merely polishes out the tangential wheel buckets, except in some few rare cases of very high head and very gritty water, where a turbine would be entirely out of question, and where even the buckets of a tangential wheel have to be renewed from time to time. There is practically no reduction in the efficiency, however, until the buckets have worn sufficiently to permit the water jet to escape without full impact.

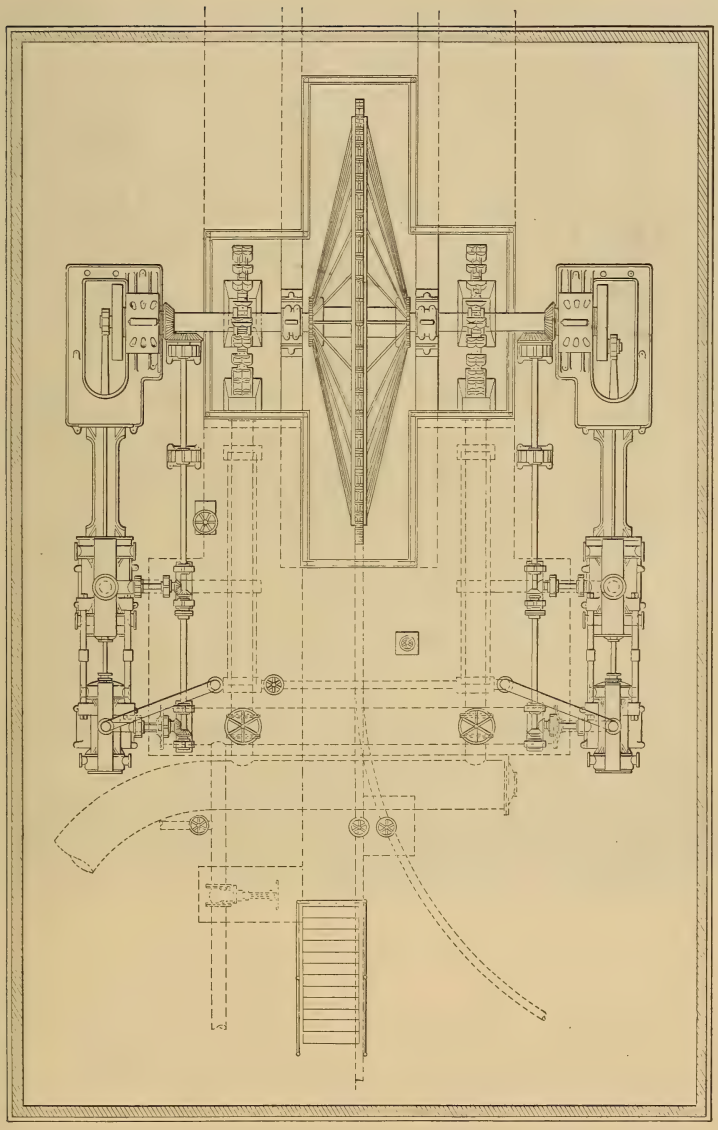
It is obvious that such a wheel will develop its maximum efficiency when the spouting water is taken up by the buckets and brought to a condition of rest with the least expenditure of frictional resistance on the bucket surfaces, in eddy currents within the bucket, and in air friction. This condition of rest, however, of the discharged water, is one of theory only, as the water must be left with sufficient velocity to properly clear itself from the following buckets. Neither can buckets be made frictionless, and there is, therefore, a point, in practice, usually less than 90 per cent., which will be the maximum obtainable under any set of conditions. The water jet is taken up on the curved surface of the bucket which it turns through nearly



A DOUBLE-DRUM GEARED HOIST DRIVEN BY TWO PELTON DISC WHEELS



ELEVATION AND SECTION OF THE AIR COMPRESSOR PLANT AT THE MORNING MINE, AT MULLAN, IN IDAHO, DRIVEN BY THREE PELTON WATER-WHEELS



A PLAN OF THE MORNING MINE INSTALLATION

A WOODEN STAVE PIPE NEAR AINSWORTH, BRITISH COLUMBIA, SUPPLYING WATER FOR AN HYDRAULIC AIR COMPRESSOR

180 degrees. The wheel should, accordingly, run at about one-half of the spouting velocity in order that the water should be brought to a condition of rest with reference to a fixed point when leaving the bucket. It will be noticed that for any given pressure a variation in the wheel diameter means variation of speed and not power, and that variation in size of jet means variation in power and not in speed.

How closely the maximum efficiency point can be reached will depend upon the skill in designing the wheels, the accuracy of the workmanship, and care in erection. Of course, these same elements are very important in determining the various other losses which occur, such as loss in supply pipe, and journal friction.

It is obvious that the higher the pressure, the greater the power obtainable from a given quantity of water, and, within certain limits, the cheaper the

power installation becomes. One of the great advantages of the tangential wheel is the ease with which it can be accommodated to the requirements of different kinds of mining machinery. Thus this form of wheel may be arranged for direct connection over a wide range of pressure, speed, and power. It may be mounted on either a horizontal or a vertical shaft, and often directly on the shaft forming part of the driven machine. In this way only a very small amount of space is taken up. If sufficient power cannot be obtained from one stream on a wheel, two, or even three jets, may be applied, or several wheels, each with several streams, may be mounted on the same shaft. By this arrangement belting is avoided, together with its losses, and much floor space is saved, and a more simple, and, therefore, more reliable and satisfactory plant is obtained.

The kind of pipe most frequently employed is one of thin sheet steel, riveted up into sections from 25 to 40 feet long. The ends may be telescoped into each other, forming what is known as a slip-joint; or they may be connected with a collar and sleeve with lead caulked between; or, where the highest pressures are employed, properly designed flanges may be riveted to each section and bolted together. Thin sheet-steel riveted pipes are frequently used under pressures of 1000 feet and more, it being considered good practice to use them with the material under a strain of quite 10,000 pounds per square inch. The water velocities employed in pipes for power are usually comparatively low to prevent the loss of pressure by friction, and if the water is purchased by measurement, a large pipe to obtain a low velocity is a good investment.

Under low pressures, up to about 150 feet head, wooden stave pipe suitably banded with steel rods, properly spaced, and each provided with turn buckles for equalising the strain, has of late come into rather extended use. The pipe is the outgrowth of the old wooden flume. The life of such a line is unusually long, and the losses in friction are very small, and in large sizes the cost is much less than in the case of steel.

Water power is particularly adapted to hoisting, and for this purpose the wheels are usually provided with deflecting ball joint nozzles or steam deflecting shields, by either of which the stream is fully removed from the wheel, although the full flow through the pipe is not altered. A very quick and easy control by the hoist operator is thus assured. By this method all variation in velocity of flow in pipes is avoided, and the water inertia is eliminated from all calculations of governing or pipe strength. Many of the ditch companies require that a constant flow be maintained at all times, on account of the necessity of delivering a fixed amount of water to a ditch of lower level or of supplying irrigation districts in the valleys below, and when this is the case the deflecting nozzle offers the best possible means of power control. Various other methods of regulation are employed, as the cut-off shield, which is fitted to slide snugly in front of the nozzle tip and against its spherical surface, and thus reduce the size of the jet. A plug nozzle is also sometimes used in special cases. Such a nozzle is one of the oldest forms of regulator, and consists of a plug arranged to move inside of, and concentric with, the tip, and so vary the area of the ring of discharge. By both this and the cut-off the pressure of discharge is retained the same at the outlet, and, therefore, a more efficient use of water is obtained, especially if the speed is to be retained constant, as, for instance, in milling, differing from compressing.

To obtain the very best results, each case requires very careful study, and the practice of referring the problems of water power development to a competent engineer or manufacturer, instead of to the millwright of some neighbouring mine, is rapidly growing in favour and resulting in the establishment of many plants of the highest degree of perfection and reliability.

It is frequently necessary to employ electric transmission to make a water power available for the use of a mining

PUTTING DOWN A 6-FOOT WOODEN PIPE FOR THE PIONEER ELECTRIC POWER COMPANY, UTAH

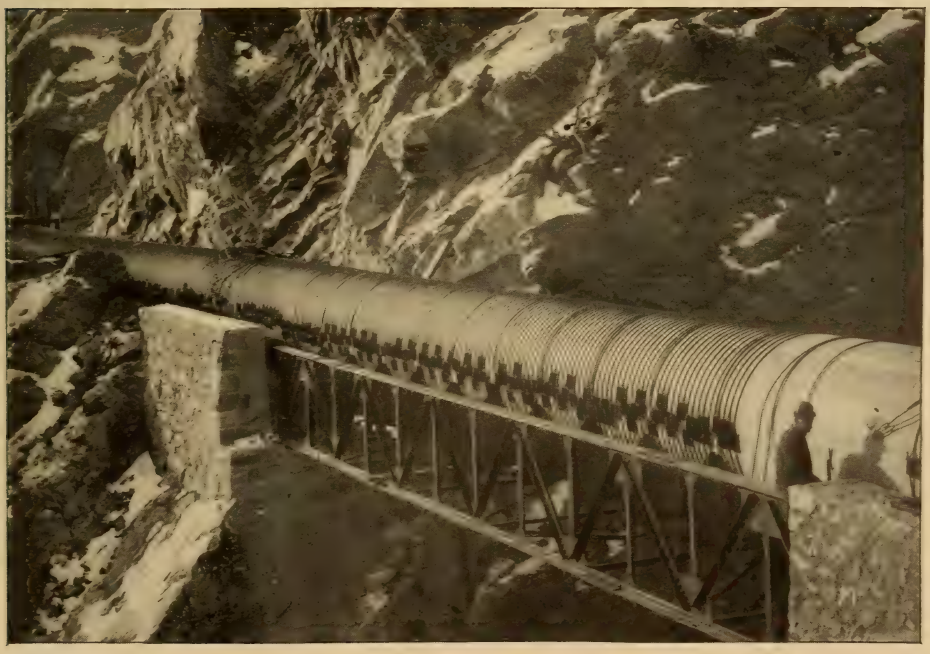
district, and the perfection to which modern electric machinery has been carried enables a very high gross efficiency to be obtained. This is the case at the Real del Monte group of mines located at Pachuca, Mexico, where a 2000 H. P. plant was installed at Regla, 4000 feet lower, and at an average distance of about twenty miles, for supplying all the mines with power, electric motors thus replacing inefficient old steam-engines that for many years had been burning coal at a cost of not less than $225, or about £45, per year per horse-power. The Comstock mines, at Virginia City, Nevada, are now being operated from the Truckee General Electric Company's plant at Floriston and there are on record numerous other instances where similar great savings are effected by large water power developments.

Other cases occur where a single mine employs a considerable power plant for its own use. The Virginius mine in Colorado employs three water power plants at different points on the same stream, all for their own require-

ments, including a 40-stamp mill, jigs, concentrators, crushers, lights, and a variety of smaller operations. The Treadwell mine, at Douglas Island, Alaska, has a great many wheels, all operated for its own use. This is one of the largest low-grade properties in the world, and the illustration on page 432 shows one of their duplex Riedler compressors, 24 × 36, driven by a 22-foot Pelton wheel under a head of 480 feet, at 75 revolutions per minute, and requiring upwards of 500 H. P. At the Utica mine, Angel's Camp, California, there are a number of Pelton wheels. The cut on page 431 shows a 5-ft. wheel with double nozzle, arranged for direct connection to a 750 KW generator, having a maximum capacity of 1200 H. P. at 400 revolutions per minute, under 530 feet head, supplying power for their various requirements. The Granite bi-metallic mines in Montana also are operated by an electric transmission from a power plant consisting of two Pelton wheels 54 inches in diameter, each direct connected by a flexible coupling to a 550 KW generator, delivering current through a bank of transformers at 15,000 volts over eleven miles of transmission line. At the mines a variety of operations are performed by the motors, including hoisting, compressing, ventilating and milling.

These are all examples of mines operated by water power from a distance, and are rather the exception than the rule, as efforts are usually made to develop the power at the mine, in which case, as pointed out above, the water-wheels are most advantageously used separately for each process. On page 430 is shown a double-drum hoist, operated by either steam or water, at the Utica mine. Water power is available during about eight months of the year, and during the remainder of the year steam is used. This hoist has a capacity of 18,500 pounds at 700 feet per minute, and each skip makes a round trip in seven minutes.

On page 433 is shown a double-drum geared hoist, using flat wire rope and showing the hydraulic controlling mechanism operated from the engineer's



ANOTHER VIEW ALONG THE PIONEER COMPANY'S PIPE LINE

stand, two Pelton steel disc wheels being used. Pages 434 and 435 show a section and plan of a compressor plant now operating at the Morning mine, at Mullan, in Idaho. The water-wheels which drive the compressors are three in number, and are mounted directly on the connecting shaft, which runs at 80 revolutions per minute. This is 15 inches in diameter, and is carried in four bearings. In the centre is mounted a 32-foot Pelton all-steel tension wheel, with a fly-wheel rim weighing 30,000 pounds. Bolted to this are cast-steel water-wheel buckets on which impinge two streams of water, one under 1130 feet and one under 1420 feet head. The wheel rim runs at 134 feet per second for normal operation. On each side of this tension wheel is an 11-foot Pelton wheel, each one receiving three streams under 140 feet head. It was necessary to develop these three different streams of water at a high efficiency to obtain enough power to work the compressors up to full capacity, and the wheel diameters were suitably proportioned to obtain a normal speed of 80 revolutions.

The water streams are controlled by steam cut-off mechanism, actuated by a specially constructed electric governor, the water flow being proportioned to the requirements of the mine for compressed air. The water mains are provided with gate valves, by-passes, and pressure gauges, all readily accessible to the engineer in charge, in the floor space between the compressor.

Many other examples exist of special applications of water power to mine development and operation, but those here cited illustrate the extremely wide field which it has filled, and help to demonstrate its importance and great intrinsic value. It is conservative to say that, in a large number of instances, especially among low-grade properties, mining not only has been made possible by the application of a suitable water power, but many more mines could not pay dividends were it not for such water power. The prospector of to-day who is wise is as careful to secure all possible water rights as he is to secure the title to mining claims.

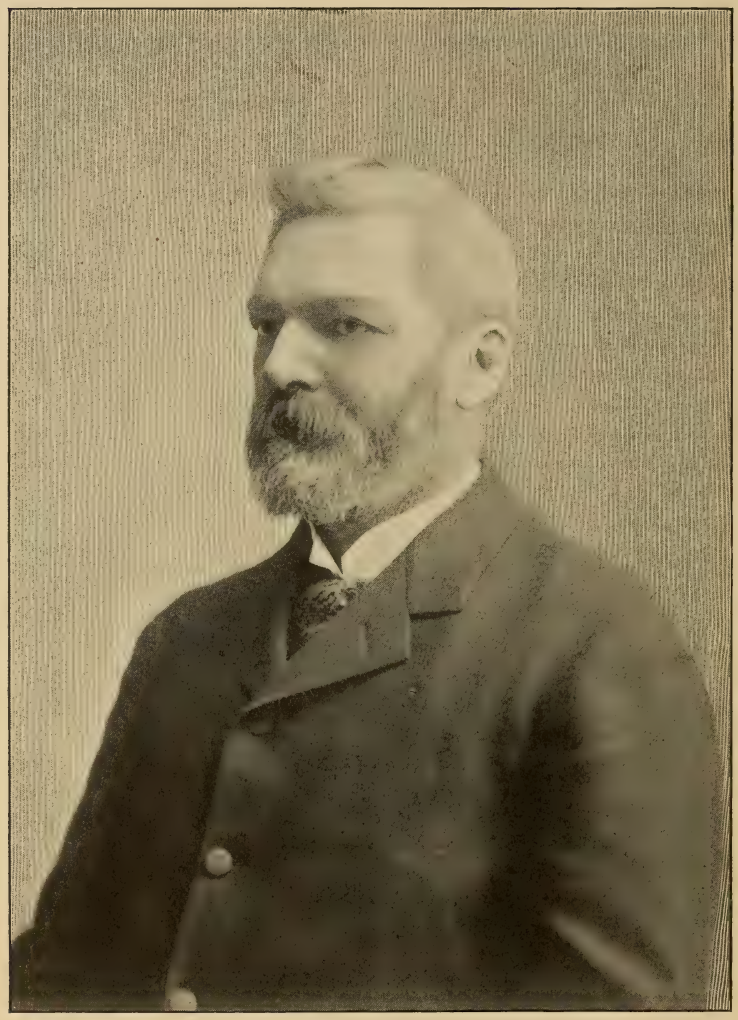


PHOTO BY DAVIS & SANFORD, NEW YORK

Washington A. Roebling

THE BUILDER OF THE BROOKLYN BRIDGE

SEE PAGE 542

CASSIER'S MAGAZINE

VOL. XXII AUGUST, 1902 No. 4

U. S. PATENT OFFICE

THE "GREAT EASTERN"

By Joseph Horner

However late the date, stories of the "Great Ship," as the *Great Eastern* was termed by our fathers in the early fifties, are still interesting. There have been many of them, and while what is told in the following pages may, therefore, not be new to all, the particulars have a fascination undimmed by the years that have gone by since that remarkable vessel started on her eventful career.

With the exception of the reproduction from a painting on page 445, the illustrations accompanying the present article have, as far as is known, never before been published. They were made from photographic negatives long since destroyed, and the portrait below of Brunel, the *Great Eastern's* illustrious designer, is the only one known to have been made of him.—THE EDITOR.

WHEN the giant frame of the *Great Eastern* was being reared on the shore of the Thames, down at Millwall, steam navigation was still young. The pioneer Cunard Company was at that time in its teens; the White Star Line was not as yet in being; and the ill-fated Collins, and the Inman, and Allan lines were in their infancy.

Atlantic liners were built of wood, steam pressures averaged from 15 to 20 pounds, and steerage passengers were not carried in steamships, but were catered for only by the sailing clipper. The run from Liverpool to New York occupied a fortnight, more or less, usually more, for the periods varied, regular running then being exceptional. Paddles were still retained, the engines were served by jet condensers, and sails supplemented coal when the winds were favourable. The only iron steamship of note then in existence was the *Great Britain*, designed by Brunel, and the experience gained in the building of this vessel led up to the *Great Eastern*.

It has long been the fashion to depreciate the labours of Brunel by reason of his costly failures; and the *Great Eastern*, the broad railway gauge, the atmospheric railway, and even the long tunnel at Box, have been adduced in justification of this criticism. But these must be regarded as the splendid errors of a pioneer, who, instead of imitating, was always original, an engineer of

A PORTRAIT OF BRUNEL SEATED BY SOME OF THE "GREAT EASTERN'S" LAUNCHING GEAR

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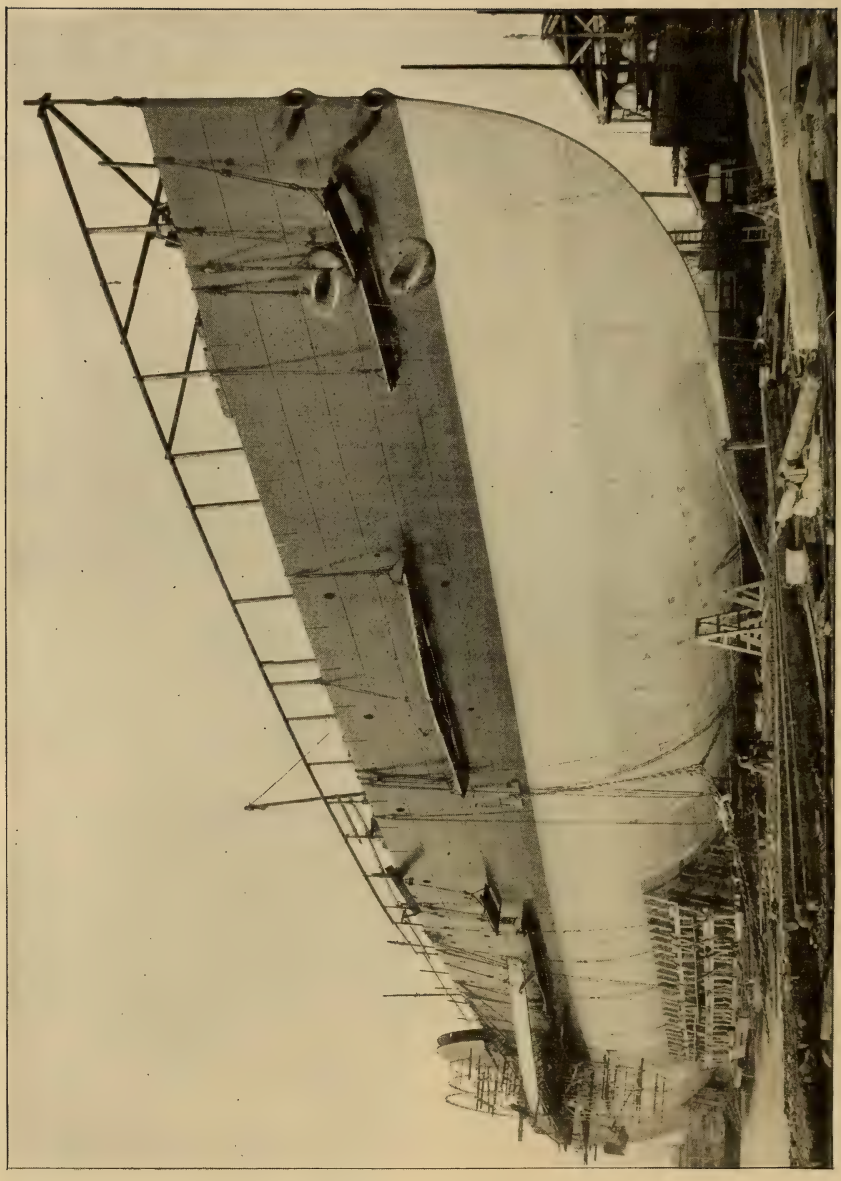
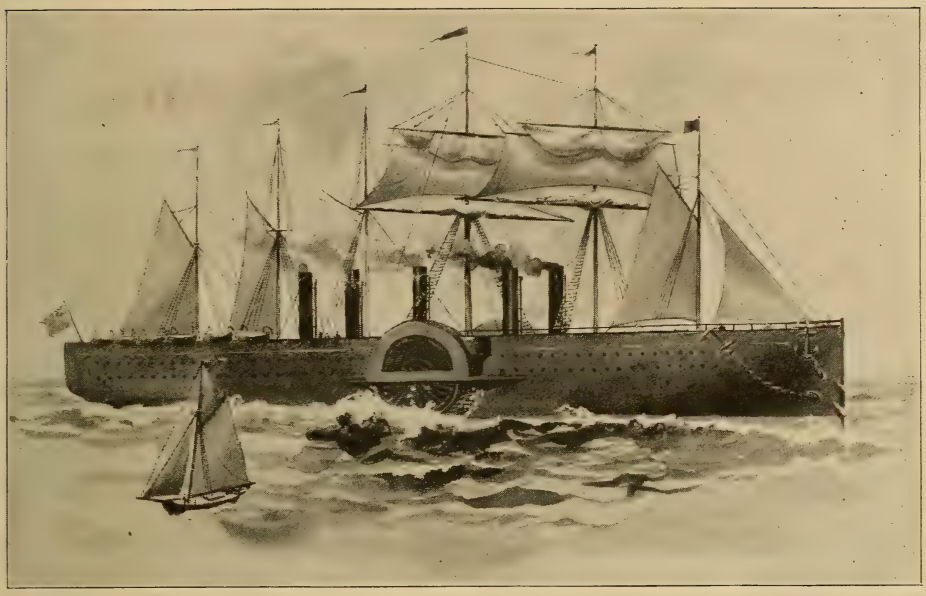


THE "GREAT EASTERN" BEFORE LAUNCHING



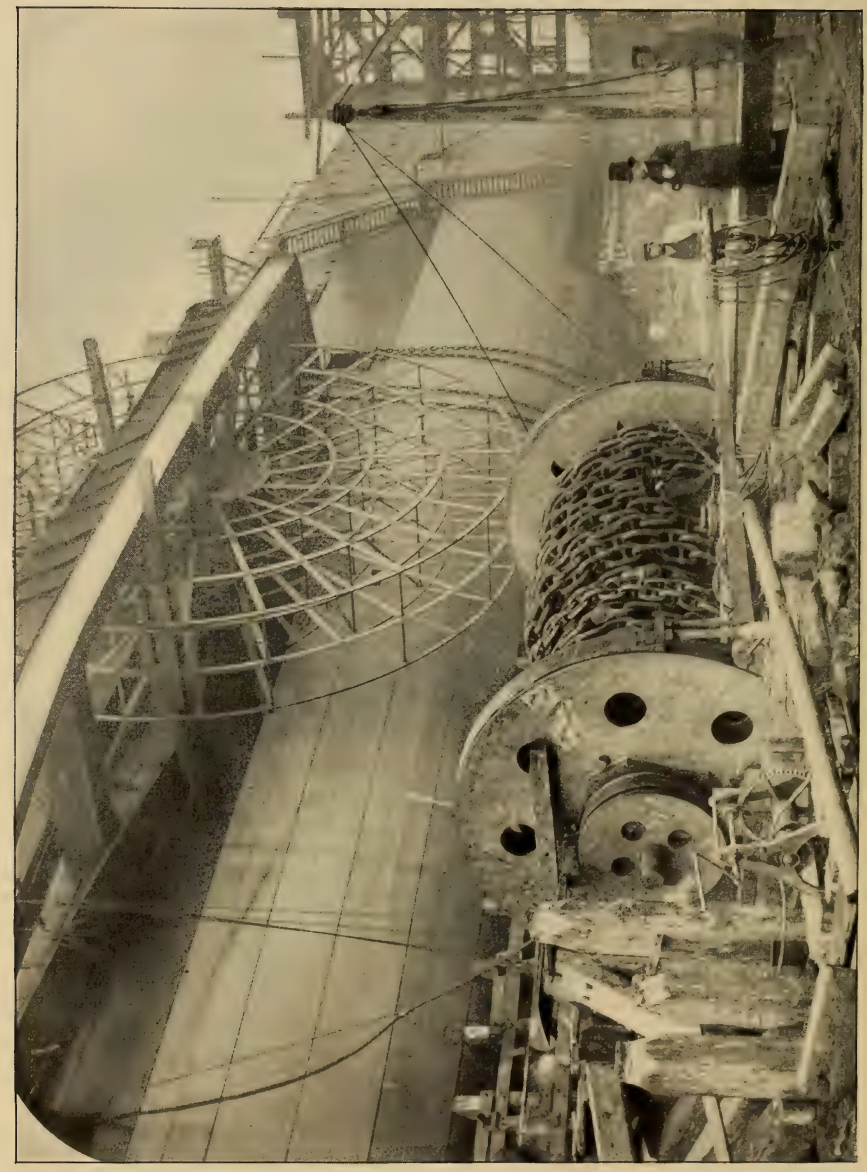
A REPRODUCTION FROM A PAINTING OF THE "GREAT EASTERN". LAUNCHED IN 1858. LENGTH OVER ALL, 691 FEET; DISPLACEMENT, 24,000 TONS; INDICATED HORSE-POWER, 8000

whose genius the profession must always be proud. The *Great Eastern* was conceived out of due time. The labours of many other men and an infinite number of developments and failures were needed to perfect the vast conceptions which were embodied in the design of the great ship.

The original scheme was that of building two big ships for the Indian and Australian service. It began to shape itself in the mind of Brunel in 1851 and 1852. He communicated his scheme to the Eastern Steam Navigation Company, a committee of the company who were appointed to confer with him and with Mr. Scott Russell reported favourably on the scheme to the directors, and Mr. Brunel was appointed engineer to the company.

It is interesting to observe, in reading the reports and letters written by Mr. Brunel at this period to the directors, and to personal friends and coadjutors respecting this work, how persistently the question of coal-carrying capacity crops up. The predominant feature in the design was that of making a vessel large enough to carry sufficient coal for the long voyage to the East. This, it must be remembered, was only fourteen years after the feat achieved by the *Great Western*,—very astonishing at that time, and pronounced impossible by Dr. Lardner,—of taking coal enough to last while crossing the Atlantic. The nature of the coal difficulty which Brunel had to surmount is explained by the fact that about that period (1852) the consumption of coal in steamships was about three and a half times what it is to-day, or nearly four pounds per I. H. P. per hour, against a trifle under a pound consumed on ocean liners at the present time.

Brunel's idea, therefore, was simply to build an iron ship of sufficiently large dimensions to take the coal necessary, over and above the accommodation required for passengers, with a reasonable quantity of cargo. He foresaw, too, what all the great steamship companies now know and act upon, that the cost of running a big ship is less than that of running several smaller ones of equal aggregate capacity. The conception was correct, but the difficulties of carrying it out were immense and, as ex-



A MIDSHIP VIEW, SHOWING ONE OF THE PADDLE WHEELS, LAUNCHING GEAR, AND MR. BRUNEL

perience proved, insuperable at that period; and there can be no doubt that the strain of the herculean and impossible task cost the great engineer his life. Shipbuilders have arrived at last at the *Oceanic*, the *Deutschland*, the *Kaiser Wilhelm der Grosse*, and the *Kron-Prinz Wilhelm*, equals in size of the *Great Eastern*, by a slow evolutionary growth.

Brunel had no such experience to draw upon. His first ideas took shape in a design of vessel which should draw from 23 to 24 feet of water when leaving the Hooghly, or 30 feet when deeply loaded, of a length of 670 feet, and 85 feet beam, containing 800 cabins, and large saloons, to accommodate from 1000 to 1500 first and second-class passengers, and 3000 tons of cargo, and having an average speed of 14 knots. This task was big enough; yet besides the enormous work of elaborating designs and preparing specifications, Mr. Brunel worked hard to get shareholders for the company.

"Could I have foreseen," he wrote, "the work I have had to go through, I would have never entered upon it; but I never flinch when I have once begun, and do it we will."

At last, after two years of preliminary work, the contracts were signed and the building began.

The Eastern Steam Navigation Company started under fair auspices, with a big capital of £1,200,000. But £600,000 of this had been spent by November, 1857, the period at which the launch was contemplated. The unfortunate delays in launching added £30,000 to the expense; it is stated that the actual cost of the launch was over £70,000. But we are anticipating.

In the spring of 1854 the ship was commenced, and from that time till early in 1858, when she was successfully launched, Brunel lived for the work, supervising all details and experiments on many matters which had a very vital bearing on the outcome of the work. In one of his numerous letters to the directors he said:—

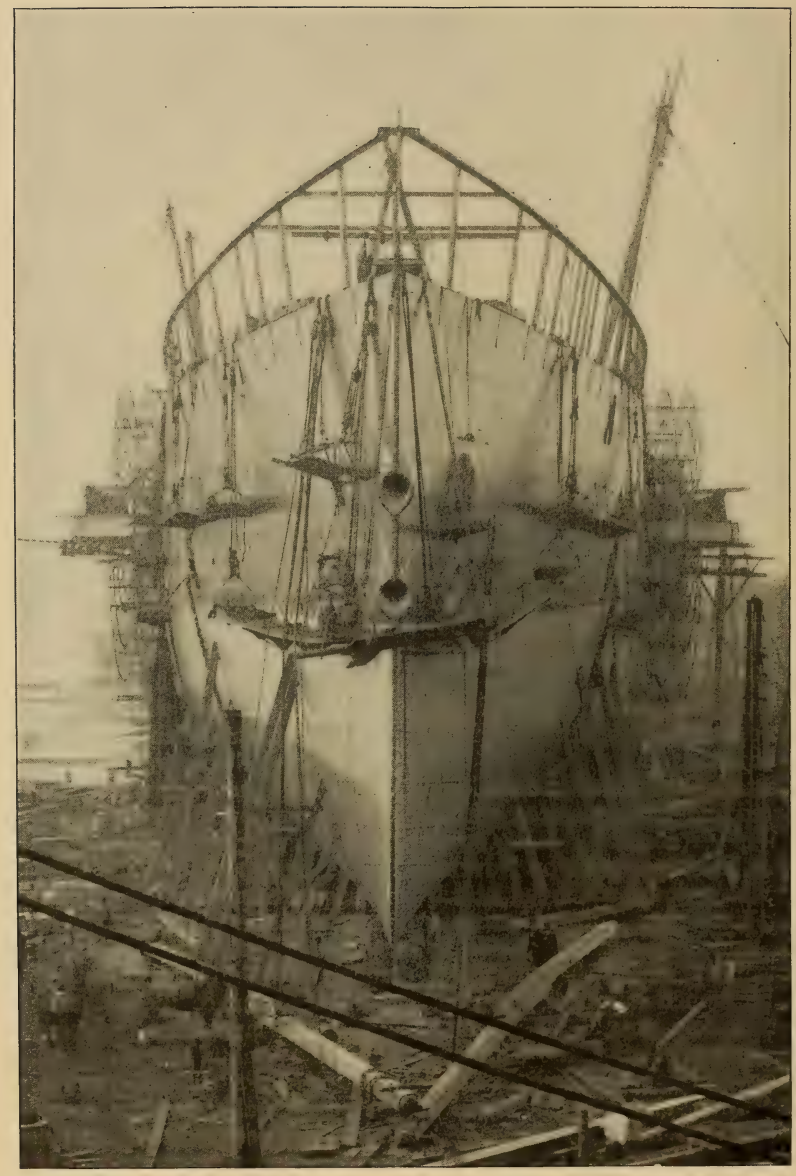
"The fact is, I never embarked on any one thing to which I have devoted so much time, thought, and labour, on the success of which I have staked so much reputation, and to which I have so largely committed myself and those who were disposed to place faith in me."

Early in 1855 the central portions of the framework of the ship, for a distance of about 400 feet, were nearly completed. To understand the sentiments with which she was regarded we must go to contemporary literature. The sober *Quarterly Review* began an article entitled "The Triton and the Minnows" in this wise:—

"The voyager up and down the Thames has noticed with astonishment, during the last eighteen months, the slow growth of a huge structure on the southern extremity of the Isle of Dogs. At first a few enormous poles alone cut the sky line, and arrested his attention; then vast plates of iron, that seemed big enough to form shields for the gods, reared themselves edgeways, at great distances apart; and as months elapsed, a wall of metal slowly arose between him and the horizon. The sooty engineer, as he leans over the bulwark of *Bridegroom No. 2*, when questioned respecting it, tells you it is the 'Big Ship.' 'Look'ee here,' says an old salt to us, pointing with his pipe to the stem and stern of the ship, which lies parallel with the river, 'here's her starn and here's her stem, and here's the water; and how they are going to launch her I can't figure noways.'"

The design of the big ship and her subsequent career will be handled presently. In the meantime, we hasten on to the period of her completion and launching in the closing months of 1857.

In the first place, the method of building and launching adopted,—with broadside on to the river, the bows pointing down stream,—was a subject settled only after anxious consideration in 1853. Vessels were, and are still, launched sideways on the great American Lakes, and pontoons had been so launched in England. But the adoption of this method proved a source of immense trouble and delay in the case of the *Great Eastern*. Many difficult details arose out of it which cannot be fully



FACING THE BOW

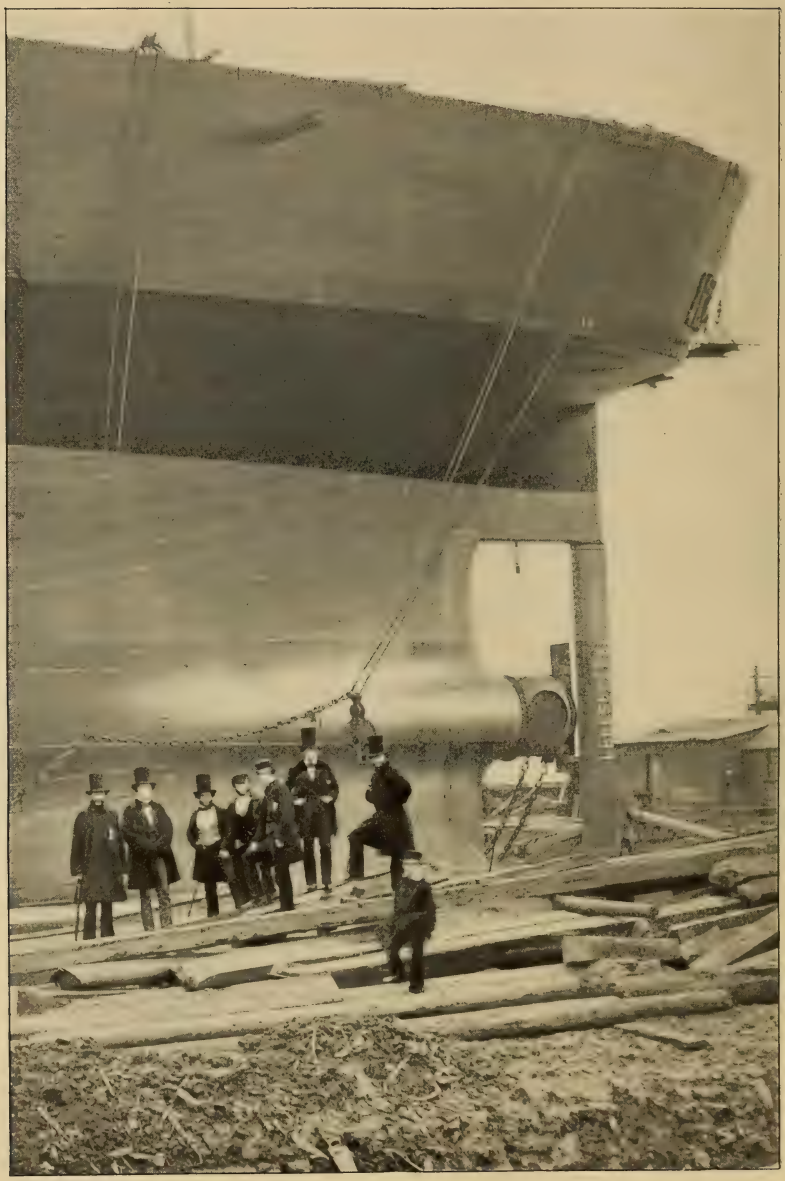
described here, but the following is a concise summary of them.

In preparing for the launch, Mr. Brunel discarded the method previously adopted of employing sliding surfaces of wood, well greased, in favour of iron ways, because of the risk of the grease being squeezed out and the wood seizing. The ship was built on cradles on the sliding ways at a distance of 240 feet from the low-water mark, measured to the starboard side. The total length of these ways was about 330 feet. The laid to form the actual sliding surfaces, —eighty rails on each of the ways. Upon these again the cradles were made to slide. These were supported on sliding bars, each measuring 1 inch thick and 7 inches wide, placed at intervals of 11 inches, and running, of course, longitudinally, or across the rails. About 60 transverse bars were placed under each cradle, which, with 80 rails under each of the ways, made about 9000 intersections of bars and rails; and as the slips and cradles weighed 12,000 tons, the

THE RESULTS OF A FUNNEL ACCIDENT DURING CONSTRUCTION

weight of the ship was distributed over a large area, the breadth of each way being 120 feet; 130 feet of the bows projected beyond the forward way, 150 feet of the stern projected beyond the after one, and 110 feet were unsupported between. The ground beneath was first prepared to a slope of 1 in 12 by a layer of concrete 2 feet in thickness. In this, timbers, 1 foot square in section, were imbedded with intervening spaces of 2 feet 6 inches. These ran down the slope towards the river. Over them, at right angles, other timbers were placed, being spaced 2 feet apart. On these rails were load on each intersection averaged 1⅓ tons.

On the sliding bars hardwood planking was fastened to carry the framing of the cradles. Tapered timbers were driven in to fill up the wedge-shaped space left between the hardwood planking and the flat portion of the ship's bottom. Means for floating the ship off the cradles were devised by the insertion of wedge-shaped pieces between the tapered timbers and the convex portion of the vessel's bottom. These were secured temporarily by long bolts to the bottom timbers. The question of moving the mass



A STERN VIEW

of 12,000 tons was a difficult one. As the ways lay at an inclination of 1 in 12, it was assumed that 1000 tons would be available, due to the action of gravity, for moving the mass down the ways. Experiments were made upon a model, and it was found that in case any considerable velocity were attained a great amount of force would be required to overcome the power of gravity. It was, therefore, determined to launch the ship slowly, keeping her movement always under control. As the sequel proved, Mr. Brunel's conclusions should have been reversed. The difficulty which he anticipated was that great retarding power would be required, once the mass were set in motion. The opposite proved to be the case, for nearly all the trouble which subsequently arose was due to the ship refusing to move down the ways, except in a jerky, spasmodic kind of fashion.

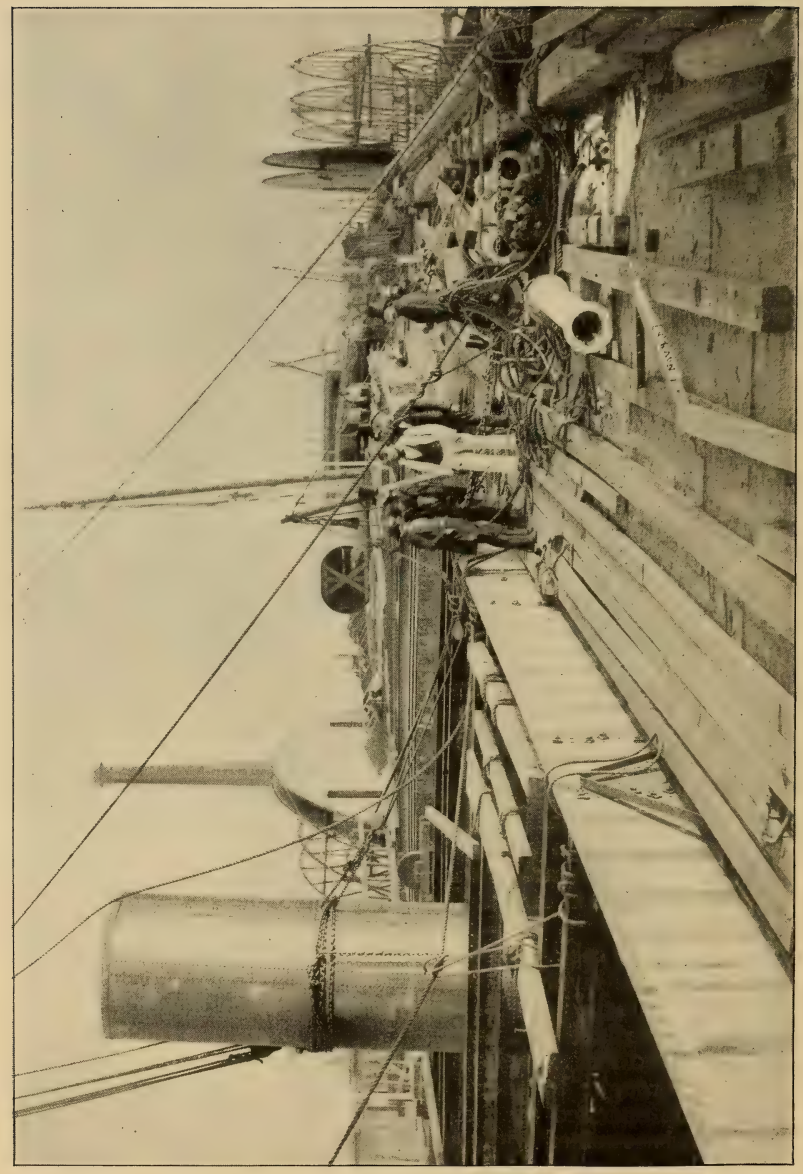
Another possible difficulty to be provided against was the flotation of the vessel off the cradles. To effect this, tackle was fitted up in the river for hauling the ship off the cradles. This was also designed for the preliminary duty of moving the ship down the ways after she had been started by hydraulic presses. This most unfortunate tackle also played very vexatious pranks in the actual launching of the vessel, and was the cause of nearly all the mishaps which arose, due to the fact that it was not tested before being put to actual service. It comprised a chain tackle secured to each end of the ship in the following manner:—

One end of a chain cable was secured to a mooring in the river and passed round a sheave attached to the ship, then round a sheave fixed on a barge in the river about 300 feet away from the vessel, thence brought to shore and hauled by tackle operated by a steam crab. The purchase gained at the stern was considered good enough for 80 tons; that at the stem for 100 tons. Another purchase of about 300 tons was applied at the centre of the ship between the cradles by means of double crabs and treble purchase blocks on four barges. The 500 tons pull estimated as available on the river tackle, with the power of two hydraulic presses of 300 tons each, and 1000 tons due to gravity, gave 2100 tons available to start the ship. Time pressed, however, and though the testing of the river tackle was determined on, it was never done, and this was the principal, and almost the only, cause of the mishaps that attended and prolonged the launching.

The means provided to check the too rapid movement were as follows:—To the land side of each cradle a strong iron framework was secured by means of bolts. This carried two large horizontal sheaves. Another horizontal sheave was fixed in a timber framing at the upper ends of the ways. Opposite the middle of the upper end a drum was placed, 6 feet 6 inches in diameter and 20 feet long. A 2⅝-inch chain cable was anchored to the framing; thence it passed around one of the sheaves on the cradle, thence around the sheave at the upper end of the ways, and from there around the second sheave on the cradle and again around the drum. The latter was operated by winch handles and a train of toothed gears. The chain was designed to be slackened by the revolution of the drums, while its rotation was retarded in case of sudden slip and of an excessive pull on the chains by means of brakes controlled by levers. But it was anticipated that the force of gravity and the retarding effect of friction would be so nearly balanced that no great exercise of power would be necessary either to move or to retard the ship down the ways. But, as already stated, more anxiety was felt in regard to the latter than the former.

At last, on November 3, 1857, Miss Hope, afterwards Duchess of Newcastle, christened the ship with champagne, saying, "God speed thee, Leviathan." The vessel moved about 3 feet, when her motion was arrested by order of Mr. Brunel, and there she stuck. The precise details of the complete launch are as follows:—

Actually, the launching occupied the dark winter weeks from the third of November, in 1857, to the last day of January in the following year. On that



A DECK VIEW DURING CONSTRUCTION

first anxious morning of November 3 the rails were rubbed over with oil and blacklead, and the shores and props were knocked away, leaving the ship resting only on her cradles. Then the dog shores were removed and the fastenings at bow and stern were let go at 12.30 o'clock. The men stationed at the winches turned the handles of the gearing to operate the drums, so giving off slack chain, and then leaned against them while hauling was being done at the bow and stern tackles and pumping at the hydraulic presses. The ship moved a few inches quickly, taking up the slack chain. Through this sudden slip the men at the forward drum were thrown into the air by the rapidly revolving handles, and the frightened brakesman ran away. Five men were thus injured, one of whom died.

It was due to a brakesman at the stern tackle, who stuck to his post, that the ship's motion was arrested after a movement of 3 feet at the forward cradle and of 4 feet 3 inches at the after cradle. The men on the centre barges moored in the stream were so frightened by the slipping of the huge mass,—supposing that they were about to be overwhelmed, one even jumping overboard,—that Brunel ordered the barges to be removed. At two o'clock another attempt was made, and then several of the teeth of one of the wheels of the bow crab broke. The intended launch was, therefore, postponed for a month, till December 2, this being the date of the next full moon spring tides.

In the interval, the four crabs and tackle from the four centre barges were transferred to the landward side of the ship, and two additional hydraulic presses were provided. These, with subsequent large additions to the number of presses, were found necessary to move the vessel down the ways; and thereby hangs a tale,—the establishment of the great business of Tangyes, Limited. In the words of Sir Richard Tangye, "we launched the *Great Eastern* and she launched us." The story, as told by him in his booklet, entitled "One and All," is as follows:—

"My brother had invented a new hydraulic lifting jack, which was just the thing that was required. One dark evening in the winter of 1856 Brunel's agent came to our little workshop, which was down an entry behind a baker's shop, the baker's oven saving us the expense of heating our workshop, and rang the bell. I opened the door; but the gentleman apologised, saying he had made a mistake, and was moving away; but I could not afford to lose a possible chance of business, and so said, 'Whose place are you looking for, sir?'

"He replied, 'Tangye's.' I told him he had come to the right place, and invited him in, when, having told us his business, he was quickly reassured upon seeing one of the machines before him. He ordered several of them; but my brother told him they would not be sufficient to effect the launch, with which opinion he did not agree." And so the hydraulic jacks ordered from time to time, beginning with the two tried on November 3, proved the foundation of the big business at Soho.

Operations were recommenced on November 19, with the result that instead of the ship moving, the timber abutments of the presses were forced back several inches. At the same time, the moving chain of the bow tackle broke. This was the beginning of a series of fractures which caused most vexatious delays. The chains should have been amply large enough if they had been sound, but link after link failed at a third of their proper strain, and each time the broken chains had to be fished up from the bottom of the river and pieced together under the disadvantages of short winter days and dense fogs.

On November 28 two chains broke at bow and stern, and some of the moorings of the barges gave way. But the ship was moved down about 14 feet as the result of the day's work. As December 2 was now very near, Mr. Brunel decided to work on the intervening Sunday, when the river tackle again failed and mooring chains snapped. The work, being thus thrown wholly on the presses, proved too great for their combined power. More of them were,

therefore, obtained, and the work went on so slowly in the afternoon, and on Monday, and the following days that the tide was lost before the ship could be launched. From December 3 to December 10 the operations were again the subject of much anxiety and of incident, the vessel moving in a succession of short slips. Not till a later date when the number of presses had been increased to nine for each of the ways, giving an aggregate power of 4500 tons, could the launch be completed.

The operations which had been suspended after December 10 were recommenced with this power available on January 5 and continued to January 14, the ship still being moved with difficulty at varying rates, making a total distance from the original position on the ways of 197 feet at the forward cradle and 207 feet at the aft cradle.

Operations were then suspended, in readiness for the high tide anticipated on January 30. At last, on January 31, the ship accomplished the remaining distance of her journey down the ways, and was floated off. But this was not accomplished without several mishaps, chief among them the fouling of one of the paddle wheels with the timbers of one of the cradles. A barge also ran foul of the other wheel, and had to be scuttled and sunk. But by seven o'clock in the evening of that eventful day the *Great Eastern* was at last moored securely on the Deptford side of the river.

The history of the *Great Eastern* afloat may be passed lightly over. This name of the ship, by the way, is not that by which she was christened. Brunel's wish was that she should be named *Great Eastern*, as a pleasing association of ideas with his first ship, the *Great Western;* but the directors overruled that, apparently because some fastidious person suggested that the name was objectionable as consisting of two adjectives. A list of names was prepared and submitted to Mr. Brunel on the day of the launch when he was anxiously engaged with more important matters. He said they might call it *Tom Thumb* if they liked. The directors then named her *Leviathan.* She appeared sometimes under one name, sometimes under the other; but the name *Great Eastern* stuck, and at last the *Leviathan* was dropped.

By the time of the launching of the ship the funds of the company had been swallowed up, and so a new one was formed,—"The Great Ship Company." Mr. Brunel's work was now nearly done. His vessel was launched at the end of January, 1858. In December of the same year ill health compelled him to go to Egypt for the winter. Returning in May, he renewed his labours, and continued to give attention to the vessel until September 5, when he left her for the last time, only two days before she was taken from her moorings. Ten days later he died while she lay off Weymouth.

When the *Great Eastern* left the Thames to go round to Weymouth, the casing of a feed-water heater exploded with fatal effects. Thence she went to Holyhead, and rode out the gale in which the *Royal Charter* was lost. The season was too far advanced for a profitable voyage to be made, and the ship was sent round to Southampton water for the winter. There Captain Harrison was drowned by the upsetting of his boat, four months after the death of Mr. Brunel. He came from the service of the Cunard Company, having been selected for the post after long and anxious thought as a man likely to be entrusted with the command of the "new machine," as Mr. Brunel termed her in his memorandum on the "Management of the Great Ship," dated October, 1855.

Captain Harrison became closely associated with Brunel during the whole of the launching operations, and the two were warm friends. He was succeeded by Captain Vine Hall, who took the *Great Eastern* on her first voyage to America, on June 17, 1860. She subsequently made nine voyages to and from America, and carried troops to Quebec, meeting with various mishaps until, in 1864, she passed into the hands of another company. After lying by for several months, she was chartered

for telegraph work and laid the first Atlantic cable, starting on her first historic voyage from Valentia on June 23, 1865. The cable broke, was three times partially raised, and lost. A second attempt with a new cable was successful, after which the old one was fished up and completed.

This period was one of intense excitement in England, the newspapers being eagerly scanned every morning for news of the cable, and it seemed as though the *Great Eastern* had found her proper work. In 1868 she laid a cable from France to America, and later one from Bombay to Aden. The last time the writer saw the *Great Eastern*, in 1887, she was a show ship in the Mersey, when the large cable tank amidships, 75 feet in diameter, was being utilised as a theatre for variety entertainments, and shilling dinners were served to trippers on board. This was not long previous to her final breaking up for old iron at New Ferry, on the Cheshire side of the Mersey.

Thus the words of the late Mr. W. S. Lindsay came true. He once offended Brunel by telling him to "turn her into a show, something attractive to the masses, for if you insist on having my opinion about her commercial capabilities, it is only in that direction where you can look for profit. She will never pay as a ship."

Comparisons have been much in favour between the *Great Eastern* and every new ship that has made a record in respect of dimensions. To the engineer, comparisons besides this one of mere size are of interest. She formed a link between the old and the new,—the use of iron as a shipbuilding material, the fitting of water-tight compartments, of a propeller, and other innovations, side by side with boilers, engines, and condensers now antiquated, low pressures, paddles, sails, an enormous coal consumption, and slow speeds.

Brunel built the great ship in water-tight compartments. She was subdivided by ten transverse bulkheads, all of which, except two, extended right across the ship to the upper deck. Partial bulkheads served to form the coal bunkers. Her bottom was made double, the two skins being of ¾-inch iron plates, about 3 feet apart. Longitudinal ribs ran between these, stiffening the ship as a girder, and forming an immense number of small, isolated compartments, into any number of which water could be admitted on either side

SOME NOTABLE STEAMSHIP DATA.

Vessel	Length Over all Feet	Displacement. Tons	Indicated Horse-Power	Speed Knots
Great Eastern	691	24,000	8,000	14 to 14½
Etruria	520	----	14,500	20
Teutonic	582	19,425	16,000	20.35
Fuerst Bismark	520	14,500	16,100	19.8
La Savoie	580	----	22,000	20.5
Campania	622	19,000	30,000	21.88
Kaiser Wilhelm der Grosse	648	20,000	28,000	23
Oceanic	705	33,500	27,000	20.50
Deutschland	686	21,000	35,000	23.51
Celtic	700	38,220	13,000	16.72
Kronprinz Wilhelm	663	21,300	33,000	23.53

to alter the trim of the ship. These extended to about 6 feet above the water level throughout the length of the ship, with the exception of the extreme ends. The upper deck also was cellular. These water-tight compartments saved the ship from wreck in American waters in 1862. She passed over a reef of sunken rocks which tore a hole in her outer skin for a length of 80 feet and a breadth of 10 feet.

The main portion of the ship,—350 feet in length,—was occupied by the engines, boilers, and coal bunkers. There were ten boilers in all, of the square box form, four for supplying steam to the paddle engines and six for the screw engines. The three boiler rooms were separated by coal bunkers. The paddle engines, of 1000 nominal horse-power, were designed and built by J. Scott Russell. They consisted of four inclined oscillating cylinders, of 14 feet piston stroke by 72 inches in diameter, the piston rod of each cylinder working on to a single crank pin. The paddle shafts were connected to the main crankshaft by means of friction clutches. These engines were made to work up to 3300 I. H. P. at eleven revolutions per minute, with steam at 15 pounds, cut-off at one-third stroke. The four boilers which served them were in two sets, each set having about

800 square feet of tube surface, and designed to supply steam at 15 pounds pressure.

The screw engines, of 1600 nominal horse-power, of the horizontal direct-acting type, were constructed by Messrs. James Watt & Co., of Soho. They comprised four cylinders of 4-foot piston stroke by 84 inches in diameter. The boilers were similar to those for the paddle engines; that is, of box form. They measured 18 feet across the fronts by 17 feet deep, and 14 feet in height, and each weighed 55 tons without water. It was anticipated that an aggregate of 10,000 I. H. P. would be developed by the paddle and screw engines. Actually they never exceeded 8000.

The paddle wheels measured 56 feet in diameter. They had thirty floats, each 13 feet broad and 3 feet deep. The propeller was 24 feet in diameter and of 44 feet pitch, with four blades, and weighed 35 tons. The ship was fitted with masts and sails according to the custom of that period.

The story of the great ship cannot be summarily dismissed as a great failure. The designing of such a vessel forty-five years ago would be paralleled, as Dr. Francis Elgar has pointed out, by the attempt at the present day to design one over 1200 feet long, of 35 knots speed. And though the greyhounds of the Atlantic now nearly equal, or exceed her in length and depth, her breadth has never been reached, and only in one case, that of the *Celtic*, has her tonnage been exceeded.

It was not the fault of Brunel that the economies of high steam pressure and of surface condensation were not then understood. He sought to solve the problem of ocean navigation by increasing coal capacity and by the use of iron in place of wood. Bunker capacity was provided for 12,000 tons of coal, a space which encroached enormously on the accommodation for cargo and passengers. Failure was due to the attempt to combine the novel with that which was rapidly passing away, the putting of new wine into old bottles; box boilers, and the rest, with the vast cellular hull; clumsy engines and paddles, with the screw, and so forth.

Ill luck dogged the ship persistently from her cradle to her grave, ruining shareholders, and causing naval engineers to fight shy of big designs until they had felt their way thereto through slow experiments.

THE MEXICAN RAILWAY SYSTEM

By Victor M. Braschi and Ezequiel Ordoñez

Of what is given in the following pages, Sections I. and II. were prepared by Mr. Braschi, while Section III. was written by Sr. Ordoñez, the whole forming one of the contributions to the meeting in Mexico, last autumn, of the American Institute of Mining Engineers. The illustrations of different features of Mexican railway engineering and the railway map on page 458 were specially prepared for use here.—THE EDITOR.

I. HISTORICAL

THE railroad history of Mexico began with the first presidential term of General Diaz. Concessions for the building of railroads had been granted in former years; indeed, an exclusive privilege was granted, August 22, 1837, to Francisco de Arrillaga for the construction of a railroad from Mexico to Vera Cruz, with a branch to Puebla, and other concessions were granted from then on at various periods; but the year 1877 was the real beginning of the regular and constant development of the railways of Mexico.

The programme laid out at that time by the new government, and responded to by the nation, was to develop its natural elements of wealth; to repeople the national territory which foreign wars and internal strife had almost depopulated; to cross the land with ample and rapid ways of communication; to open new markets to Mexican products; to increase internal trade; to end at once and forever fiscal penury and its fatal, and until then inevitable, consequences; to re-establish the lost national credit; to diffuse popular instruction; and, finally, to promote in every way public and private prosperity, thus redeeming the nation from the double slavery o ignorance and poverty, and elevating it, through its wealth and power, to the high level that it ought to occupy among

RAILWAY BRIDGE ACROSS THE RIO GRANDE AT CIUDAD PORFIRIO DIAZ

MAP OF MEXICO SHOWING MORE PARTICULARLY THE LINES OF THE MEXICAN CENTRAL RAILWAY

civilised nations. To establish and insure peace, it was necessary to join the integral parts of the country by means of rapid ways of transit, a military strategical necessity, because, in the words of General Diaz, "unstable and changeable governments, incapable of protecting life and property, either end in absorption by a stronger people or use themselves up and disappear, without leaving in history other traces than sometimes those of their heroism, but more often the remembrance of their misery and sufferings."

Moreover, beyond their military significance, such means of rapid and easy internal transportation, permitting freedom of travel, trade and correspondence, would stimulate enterprise, increase production, and promote the growth of both general intelligence and national wealth.

The technical problem of Mexico's rapid and economical means of com-

munication was not difficult. On the map, Mexico has the shape of a leg of mutton, wide at the north, its coast-lines joining in curves to form to the south the isthmus of Tehuantepec. It is without navigable rivers, except in the narrow and uncultivated mountainous and tropical regions of the south; and there are two formidable systems of mountains parallel to the coasts, forming in the centre of the country the great table-land of Mexico, inhabited by about half the total population. This table-land has the same general shape as the country, namely, an oblique triangle, with its base upon the northern frontier of the Rio Grande and its apex about in the valley of the City of Mexico. South of this valley the two coast systems of mountains mix and join, so that the rest of the country down to the isthmus of Tehuantepec is mountainous, with the exception, of course, of the flat coast fringes. The central table-land is not absolutely level, but slopes northward to the Rio Grande, and is crossed by numerous separate systems of mountains and hills, independent of the two coast ranges.

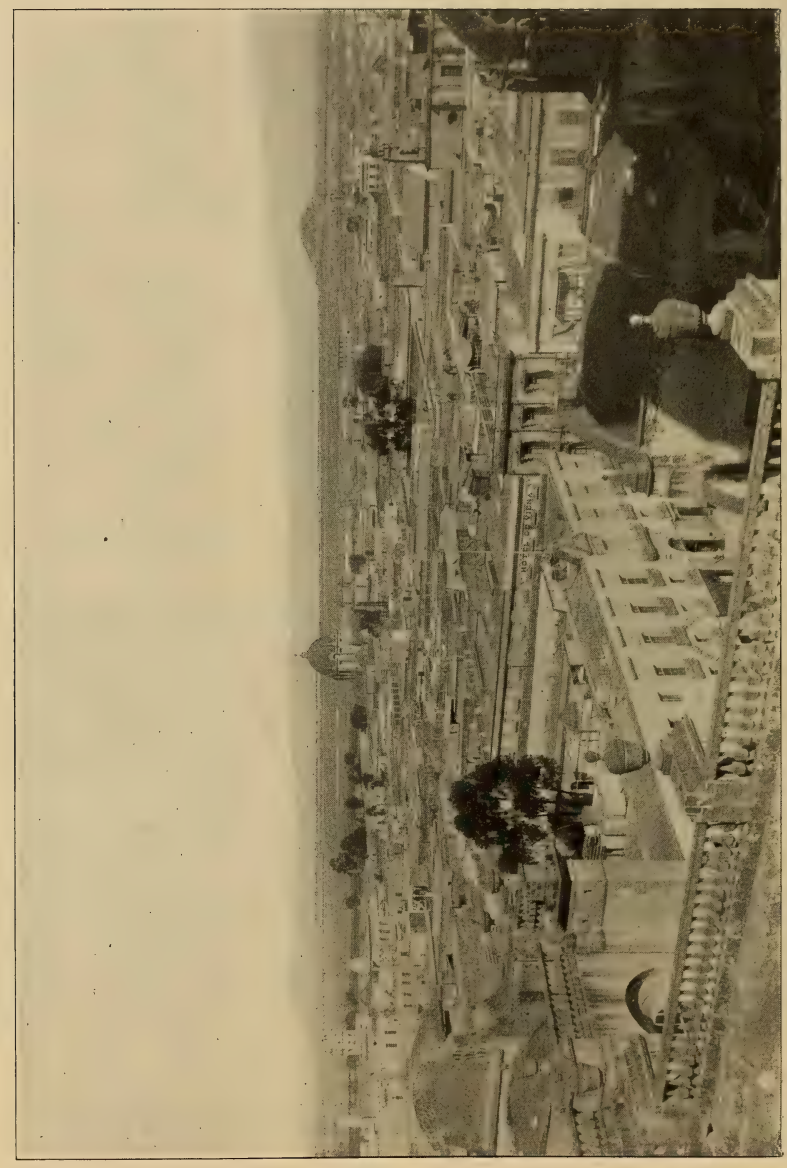
The population of Mexico is distributed roughly as follows:—

	Per Cent.
Central States	47
Pacific Coast States	33
Gulf of Mexico States	12
Northern Frontier	8
Total	100

In 1877 the central table-land, containing about half the population, and which is the true and typical Mexico, was thus separated from the coast by two systems of mountain ranges, and its own principal subdivisions were separated by long distances, occupied by large, uncultivated, and almost desert territories. The north, with its long, thinly-settled frontier, and only 8 per cent. of the total population, was indeed a free and wide field for insurrection and smuggling. The Pacific coast States, with one-third of the population, were entirely separated from the rest of the country by the Sierra Madre Mountains. These physical barriers, of course, still remain; but statesmanship and enterprise have so far overcome them that they are no longer absolute barriers. It is as if they had been half obliterated.

Mexico, therefore, was then a nation composed of almost independent provinces or petty States, united only by a common language, origin and history, and by memories of a common resistance to two foreign aggressions, notwithstanding which they tore one another up in internal fratricidal wars. These States, separated by difficult mountains and extensive deserts, had accentuated their natural isolation by raising against each other artificial walls in the shape of interior custom houses; and their highways were infested by bandits, en-

THE MEXICAN CENTRAL RAILWAY STATION IN THE CITY OF MEXICO



PANORAMA OF THE CITY OF MEXICO

couraged by the long intervals between cities, and by repeated revolutionary disorders. When the modern history of Mexico began in 1877, the country was anxious and ready for a change.

The topographical and geographical distribution of the population being such as we have seen, and no navigable rivers existing in the populated portion of the country, the engineering scheme for rapid ways of transit proposed, of course, a net of railroads. This was composed, broadly speaking, of the following systems:—

1.—Lines which, starting from various points on the northern frontier upon the Rio Grande, should cross the great central table-land, converging to the capital, the apex of the triangle of the table-land. These lines would join the capital to the central and northern States, and, crossing vast uncultivated territories, would connect with the railroad systems of the United States.

2.—Lines which, starting from the Gulf of Mexico, should climb the east or Gulf range of mountains, to join the central table-land with the Gulf.

3.—Lines which, starting from the City of Mexico and its neighbourhood, should invade the mountainous regions of the South and South Pacific.

4.—Lines which, crossing the Sierra Madre from any possible point on the West, should join the Pacific coast with the centre and the Gulf.

5.—Subsidiary lines and branches.

In general, these theoretical railway schemes had, of course, been understood in early days; and, as already stated, a concession had been granted in 1837 for a railroad from Vera Cruz to Mexico,—the line which had always been considered indispensable, since Vera Cruz had always been the chief port of the Republic; but nothing of practical import was done until 1877, when the government wisely began the granting of pecuniary assistance to railroad building as a regular official policy.

THE CANAL DUG BY CORTEZ TO DRAIN THE VALLEY OF MEXICO CITY

When the new government of General Diaz took hold of affairs, the only completed through line was the Mexican Railway, 255 miles long, from Vera Cruz to Mexico. Besides this, there were the branch to Puebla; the line from the port of Progreso to Mérida, the capital of Yucatán; the short line from Vera Cruz to the port of Alvarado; and a few miles of the Mexican Na-

RAILWAY THROUGH DOLORES CEMETERY, NEAR THE CITY OF MEXICO

tional, just starting to Toluca; making a total length in 1877 (including the lines of the Federal District) of 672 kilom., or 417.5 miles. Ten years afterwards the length of railways was 6,608.809 kilom., or 4106 miles. In 1897 the length was 11,772.642 kilom., or 7311 miles, and in September, 1901, the total was already 15,454 kilom., or 9600 miles.

II. PRESENT CONDITIONS

Grouped under the five systems above sketched out, the various present lines and branches appear as follows:—

I.—From the Rio Grande to the City of Mexico.

	Miles
Mexican Central: Ciudad Juárez to Mexico City, 1970.44 kilom	1,225
Mexican National: Laredo to Mexico City, 1350.44 kilom	841
Mexican International: Ciudad Porfirio Díaz to Torreón, 616.55 kilom	383

II.—From the Gulf of Mexico to the Table-Land.

	Miles
Mexican Railway: Vera Cruz to Mexico City, 423.75 kilom	263
Interoceanic Railway: Vera Cruz to Mexico City, 646.602 kilom	340
Monterey and Mexican Gulf: Tampico to Treviño, 624.64 kilom	387
Mexican Central: Tampico to Aguascalientes (Chicalote), 653.5 kilom	412
The Hidalgo and North Eastern Railroad belongs also in this system. It starts at Mexico City and goes to Pachuca, branching off at Tepa for Tulancingo, and will eventually reach the Gulf of Mexico at the port of Tuxpan. Its ramifications, making a unique system, owned and handled entirely by Mexicans, amount in length to 212 kilom	132

III.—From the City of Mexico and Neighborhood to the South and South Pacific.

	Miles
Matamoros Branch of the Interoceanic: Puebla to Tlancualpican, 124 kilom	77
Morelos Branch of the Interoceanic: Mexico to Ixtla, 216 kilom	134
Mexico, Cuernavaca and Pacific: Mexico to Rio Balsas, 292 kilom	181
Mexican Southern: Puebla to Oaxaca, 367 kilom	227

IV.—Across the Sierra Madre to the Pacific Coast.

	Miles
Sonora Railroad: Nogales to Guaymas, 426 kilom	265
Rio Grande, Sierra Madre and Pacific: Ciudad Juárez to Terrazas, 250 kilom	156
Parral Branch of the Mexican Central: Jiménez to Stallforth, 134 kilom	84
Chihuahua al Pacifico: Chihuahua to Miñaca, 200 kilom	124
The Torreón to Durango line of the International: 253 kilom	157
The Manzanillo Branch of the Mexican Central, now under construction from Guadalajara, has built 192 kilom	119
Occidental Railroad: Altata to Culiacán, 61 kilom	38

V.—It is unnecessary to mention the various lines and branches that belong in the subsidiary, purely local system, of

which the Mexican Northern, between Escalón and Sierra Mojada, may be taken as a type. The branches of the Central throughout the State of Jalisco, and the National's branch to Morelia and Uruapam, in Michoacán, are also of great local importance.

VI.—A sixth system might be said to consist of the Tehuantepec Railroad, owned by the government, between Coatzacoalcos on the Gulf and Salina Cruz on the Pacific, 192 miles long,—a road that will play an important part in Asiatic trade as soon as these two ports, now in course of improvement, are ready for trans-continental business. This road will be joined shortly to Vera Cruz by the Vera Cruz & Pacific Railroad, which, starting at Córdoba, on the Mexican Railway, will connect with Santa Lucrecia, on the Tehuantepec. About 125 miles of this new road are now built.

III. A RAILROAD JOURNEY

Under this head it is proposed to give an account of what can be observed by a traveller following the lines of the Mexican railways. For the sake of clearness and completeness, some features of the topography already mentioned are re-stated.

The Isthmian region begins in the Mexican territory, situated south of the United States, between the two oceans. It extends to the south by a series of narrow isthmuses, forming Central America, which was probably formerly joined to the Antilles, and constituted, as has been noted by several observers, a region similar to the Mediterranean zone between Europe and Africa.

The general shape of Mexico is that of a strip of land gradually narrowing towards the south, and widening again to the southeast. It branches off towards the Isthmus of Te huantepec in a very irregular strip of land, which constitutes Central America, and in another, which extends towards the Antilles, and is called the Peninsula of Yucatán.

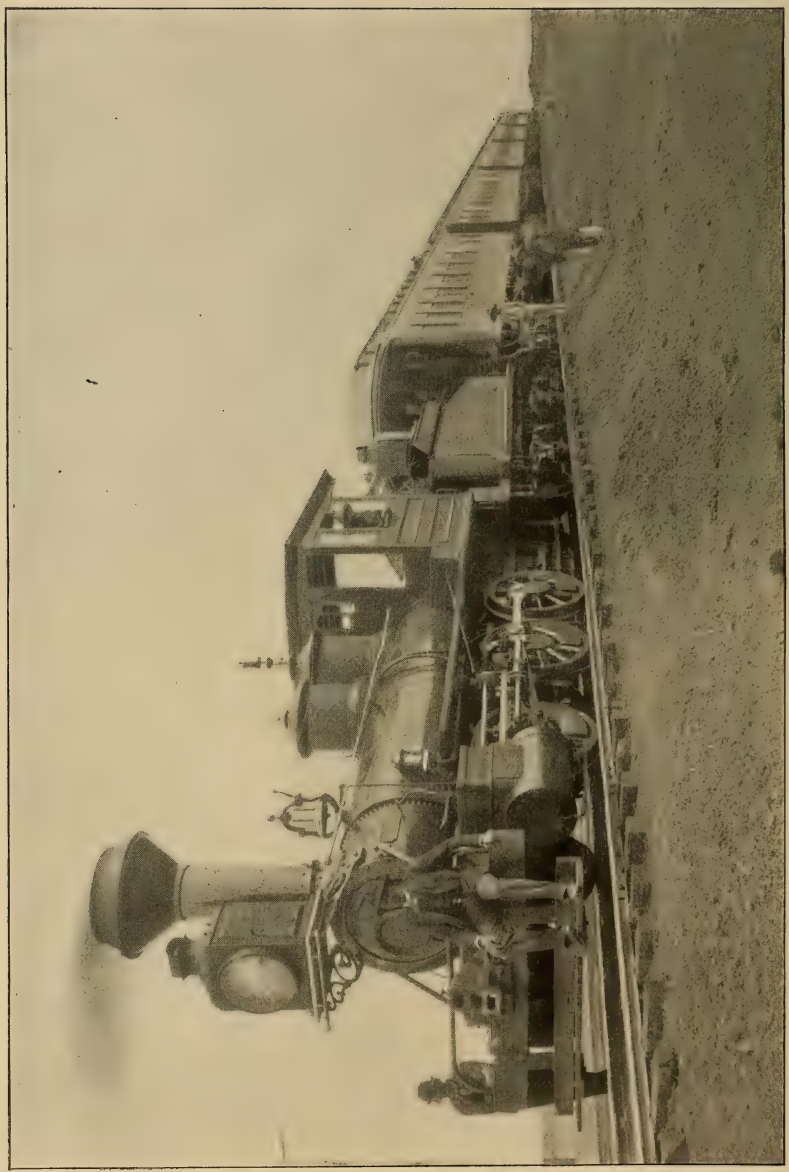
The Peninsula of Lower California is a prolongation of the coast line of the Northwestern States, from which it is actually separated by an arm of the sea called Cortes, whose entrance is formed by San Lucas and Corrientes capes, thus establishing not only a geographical extension, but also a strictly geological dependence.

The most rudimentary idea which could be furnished of the general structure of Mexico would be to compare it with an immense continental plateau supported and bounded by two ranges of mountains parallel and close to the littorals of the Gulf and that of the Pacific Ocean.

These two large chains of mountains, which are orographic continuations of the Rocky Mountains, have a tendency to join in the shape of a V, whose branches are united in the network of mountains of Oaxaca. Naturally, near the vertex of this large V is the highest elevation of the plateau, which gradually declines towards the north.

The two mighty mountain-chains, called by Humboldt the Mexican Andes, and well known as the Sierra Madre

A HEAVY GRADE ON THE LINE TO VERA CRUZ



A TRAIN ON THE MEXICAN CENTRAL RAILWAY

Oriental and the Sierra Madre Occidental, are not single ranges. Each is a continued series of groups of ranges, or of isolated mountains, separated by cañons and deep ravines traversed by torrential waters. And they present magnificent forests, where one enjoys all climates giving life to the landscape, or arid slopes, scattered with naked rocks, and containing a network of metalliferous veins, which furnished the traditional romantic wealth of the Toltecs, Mexicans, and other opulent aboriginal races.

The great plateau called Mesa Central (5600 feet average height above sea-level and about 257,000 square miles in area) extends from the plains of Texas and New Mexico, in the United States, to the base of the volcano of Xinantecatl, on the Nevado de Toluca, at the foot of which the central plateau has an altitude of 2600 meters. Deep, splendid cañons through the two great Cordilleras permit the waters of the interior to reach the wonderfully fertile and beautiful coast.

The traveller across the extensive desert plains of Texas finds no variation in the landscape on reaching the right bank of the Rio Grande. The cultivated prairies surrounding the well-painted frame-houses where the cowboy, the Anglo-Saxon ranchero, dwells, the humble hut, lost in the immensity of the Mexican plains, and the cabin of the Indian or creole labourer, are not sufficient to relieve the lonely monotony.

Small streams cross the Mexican Central Railway, which, after running many miles through clouds of dust, finally reaches an oasis.

Chihuahua, the capital of the State of the same name, is the most important in Northwestern Mexico. Its 20,000 inhabitants are divided between manufacturing and industrial pursuits, and its prosperity is largely due to the neighbouring mining district of Santa Eulalia, formerly famous, and now inaugurating a new period of prosperous productiveness. The city of Chihuahua has been remarkable since 1718.

WAITING FOR THE WRECKING CREW

Going south, the railway skirts the plains of Bolson de Mapimi, bounded at this part by the Conchos River, one of the affluents of the Bravo, which crosses the line above the city of Santa Rosalia; three hours afterwards one reaches the city of Jiménez, an ancient military post

RUNNING THROUGH A COFFEE TRACT

of the Colonial epoch, and at present the junction of the Parral branch. Parral is at present one of the most flourishing mining districts of the Republic.

After passing the station of Escalon, the junction of the line to the Sierra Mojada, a rich mining district discovered some twenty-three years ago, the railway, before reaching the station of Jimulco, traverses the principal cotton district of Mexico, in the region of the plains fertilised by the waters of old lakes, such as Mayran and Tlahualilo, fed by the Nazas River, which rises in the slope of the Sierra Madre, in the State of Durango, and the Aguaravel River, which empties into the Patos and Parras lakes. This region has been converted into an important manufacturing and industrial centre. The present generation has seen the rapid growth of business towns like Ciudad Gómez, Palacio and Torreón, the latter of which is now the junction of two railroads of mighty significance and influence in the economical progress of the country. Torreón is connected with the city of Durango, from which the road to Mazatlán, on the Pacific Ocean, has been projected and begun. It is also the terminus of the International Railroad, the other route which connects on the United States border, at the city of Porfirio Diaz, with the Southern Pacific. At Reata this railway connects with the Gulf Railroad, which, touching Monterey, the capital of the State of Nuevo Léon, and passing through the cities of Cadereyta, Montemorelos and Victoria, arrives at the port of Tampico.

Following the banks of the Aguanaval River, the road leaves the station of Jimulco to enter anew the desert plains, bounded by a horizon of high mountain ranges, utterly devoid of vegetation.

To the left of the station of Camacho the peak of Teira, at the base of which narrow auriferous veins are worked, towers from a large mountain range. Behind this mountain are the Zuloaga, Mazapil, Concepción del Oro and Candelaria ranges, which contain important

mineral deposits of ancient and modern exploitation. To the right of the station of Gutiérrez are seen the low foot-hills of the Western Sierra Madre, beyond which are the mining districts of Nieves and Sombrerete, of old mineral development.

The plain changes gradually into valleys less arid and better irrigated; cultivation begins to appear before reaching the lowlands of Calera, which is a continuation of the salt plains and bogs of the village of Cos, and shortly before this the station of Fresnillo is reached, not far from the rich mining district of the same name, discovered in 1554 and worked (especially as to the group of veins of Proaño hill) since the eighteenth century. This mining district has undergone many changes; several important bonanzas were extracted in the first half of the nineteenth century. The workings having had a great development and impulse, it was decided in 1853 to install there the practical School of Mines for students of the Mining School of Mexico.

A little further beyond the station of Calera the road begins to ascend towards the foot-hills of the Zacatecas range, until it reaches a height of about 8000 feet above sea-level, the highest on the line from El Paso to the City of Mexico.

The route of the railroad over these mountains presents a wonderful and interesting panorama. Following the ins and outs of the mountains, it frequently invades the mining claims, whose cornerstones look like white dots on the barren slopes of the hills; improvements, such as stacks of boilers, hoisting works, roads and trails, are noticed everywhere in the vicinity of the shaft openings. Finally, the eye is suddenly met by the confused groups of houses of the city of Zacatecas, at the bottom of a depression surrounded by high mountains, the most distinguished of which is La Bufa, a mass of rhyolite which crowns the range as a crest.

The cupolas and towers of the churches, the roof of the market and the high façade of the theatre tower up in the midst of the houses, which, with their plain roofs, bear at a distance the aspect of a pile of blocks.

The city was founded in 1585, the rich mining district, one of the greatest developed in Mexico, having been discovered by Juan de Tolosa in 1546. Philip I. granted to the city the privileges which those of Castile used to

AN ENGINE AND WATER CAR

THE CATHEDRAL AT CHIHUAHUA

enjoy. The mining district is at present in the most deplorable state of decline, as is indicated by the imposing ruins of its mills, many of which are located in the Guadalupe cañon, skirted by the railroad.

The line now descends from the Zacatecas range to enter anew the plateaus where pastures and productive fields abound. Three hours later the traveller begins to distinguish the smoke of the chimneys of the great foundries in the environments of Aguascalientes, capital of the State of the same name, an agricultural and industrial city of 30,000 inhabitants, situated 6000 feet above sea-level, and founded in 1575. It owes its name to hot springs found in the immediate neighbourhood. This is a beautiful city, with numerous orchards and churches. Its peaceful inhabitants are devoted to agriculture and the arts. They are famous as weavers, and for the handiwork of the women, who come to

offer their wares at the car windows. South of Aguascalientes, land of a better quality and well irrigated has favoured the growth of a number of towns and cities. This region, up to the City of Mexico, is essentially agricultural, and constitutes the most densely populated part of the country. About an hour after leaving Aguascalientes the traveller passes through the village of Encarnación, built on the rolling arid hills between the windings of a river, which the Mexican Central crosses by a magnificent iron bridge.

The town of Lagos, the county-seat of one of the districts of the large State of Jalisco, is 6200 feet above sea-level, has an excellent climate and 15,000 industrious inhabitants, and was founded by Francisco Martel in 1563, with the purpose of facilitating the subjection of the Chichimeca Indians, who inhabited that region. It has also a famous church.

León, the second city of the State of Guanajuato, very important for its industries and commerce, situated at the foot of the valley, surrounded by hills and rocky plateaus, was founded in 1576, during the reign of Philip II. of Spain. The population, which is 60,000 to-day, has been, in prosperous times, as large as 100,000. In 1888 a terrible inundation destroyed the greater part of the city, and more than 200 persons lost their lives, while more than 20,000 were made homeless. A national subscription and the honourable efforts of the inhabitants have resulted in the reconstruction of the greater part of the town. The tanneries of this city are the most famous in the country, furnishing especially the leather for Mexican saddles and the traditional "charro" suits.

León is situated in the extreme northwest of a region specially favourable for the cultivation of cereals, by reason not only of its rich soil, of a porous volcanic formation, but also of the remarkable regularity of the rains, giving an opportunity to take advantage, for irrigation, of the waters of the important Lerma River, and some other water reservoirs.

This region, shaped like a pail or wooden bowl, and bristling with mountains and volcanic hills, bears the name of Bajío, and was called in times past the granary of the central part of Mexico. The southern limit of the Bajío proper extends to the city of Querétaro; that is to say, it has a length of nearly 90 miles, bounded by strips of rhyolitic plateaus or high mountains, such as the Guanajuato range on the east and the Pénjamo on the west. This is the most densely populated region of the Republic. Its numerous plantations, villages, towns and cities, connected by excellent roads, together with the railroad, give the Bajío a commercial and agricultural importance not realised in any other part of the country.

After a ride of two hours through rocky table-lands, bounding the fertile plains, which widen gradually, the beautiful city of Silao de Victoria is reached, almost at the foot of the Guanajuato range, celebrated in the annals of the country for the wonderful richness of its veins, which have been worked since the remote days of the Conquest. This town, 6000 feet above sea-level, and now possessing 15,000 inhabitants, was at the beginning a miserable village of Chichimeca Indians, first known by Nuño de Guzmán. About 1553 various Spanish families settled there, and gave to the place the name of a plant called Silao, which grows abundantly in the vicinity. The later name of Silao de la Victoria was given on account of a bloody combat between the armed Liberals and the revolutionary armies of General Miramón.

The city is noted for the regularity of its streets, the cleanliness and simplicity of its houses, its ample public squares and its beautiful parish church, constructed in the eighteenth century. Hot springs are found near the town and on the slopes of the Guanajuato range. From the railway station the peak of El Cubilete towers to a height of 8300 feet above sea-level. A branch of the Mexican Central brings the traveller in two hours to the station of Marfil, above the open cañon which ends at the city of Guanajuato.

The old town of Irapuato, founded in

MAXIMILIAN'S PRISON AT QUERETARO

1547 by an edict of Charles V., is noted for its active commerce, its hand-weaving industry, and the beauty of the exterior of its temples. In 1812 it was attacked by the insurgents and almost completely destroyed. In its innumerable orchards are cultivated with special care the strawberries which are principally consumed in the City of Mexico. These orchards are irrigated by water drawn from shallow pools by means of primitive well-sweeps. Salamanca is in the centre of the Bajío, on the right bank of the Lerma River, on the broad, low, and fertile plain of black volcanic soil which becomes inundated during the rainy season, forming in some places extensive swamps. It has fine churches, and the ruins of an ancient convent, and its inhabitants are industrious and skillful agriculturists. A street railway connects it with the city of Valle de Santiago, a fertile valley surrounded by extensive, crater-like lakes, called "ollas" (earthen pots). Valle de Santiago is noted for its specialty of rebozo weaving.

WHERE MAXIMILIAN WAS EXECUTED

Celaya is one of the largest cities of the Bajío, being next in importance to Querétaro and León. It is situated on a plain at an altitude of 5900 feet; was founded in 1570, and was peopled at first by Vizcainos, who gave it the Vasco name of Zalaya, that is to say, "Plain-land." The first inhabitants

had bloody encounters with the Chichimeca Indians, whom they succeeded in conquering. After that, the population increased rapidly, and has been energetically devoted to the cultivation of the land, which has been gradually irrigated by the waters of the Laja River, running near the city. Magnificent plantations, covered with huizaches, mesquites and other trees, surround the city. It has a number of large buildings, among which is the Carmen Church, the façade of which is of Corinthian style, a work of the famous native architect, Tresguerras, born in 1745. In the interior of this church some paintings by celebrated native artists are much admired. Like the other towns of the Bajío region, the inhabitants, besides being agriculturists, are devoted to the weaving industry. The two main railroads of Mexico, the Mexican Central and the National, cross each other at the edge of the city, each having its own station.

A TYPICAL MEXICAN RESIDENCE IN THE CITY OF MEXICO

Querétaro, the capital of the State of the same name, situated at the southern limit of the Bajío, has 35,000 inhabitants. It is an ancient Tarascan city, was subject to the crown of Montezuma I. about 1445, and conquered in 1531 by Fernando de Tapia. In 1655 Philip IV. conceded to it the rank of a city. It can properly be called to-day the city of churches, as it has sixteen large ones, many of them containing fine works of art in sculpture, paintings and wood-carvings, which, together with its cloth, blanket and rebozo industry, have made it famous in the past. Close to the city is the large Hércules cotton cloth factory, partly run by water-power furnished by a magnificent stone aqueduct. The railroad passes underneath one of its gigantic arches. The construction of this aqueduct was commenced in December, 1726. At present the factory employs 1500 operators.

Querétaro has suffered in recent years a notable decline and loss of its supremacy in its industries. About the middle of the past century it reached a

HOLE IN THE MOUNTAIN, BETWEEN MONTEREY AND SALTILLO, ON THE MEXICAN NATIONAL RAILWAY. TO THE NAKED EYE THE HOLE APPEARS TO BE PERFECTLY ROUND, AND THE LIGHT SHINING THROUGH IT SUGGESTS AN OPTICAL ILLUSION. THE TRAIN MEN ON THAT PART OF THE LINE ARE INCLINED TO THE BELIEF THAT THE HOLE WAS SHOT THROUGH THE RANGE WITH A HEAVY SIEGE CANNON DURING THE WAR BETWEEN MEXICO AND THE UNITED STATES IN 1847

population of 50,000 inhabitants. It has always been an important theatre of political affairs. Here were held the famous meetings which prepared the glorious Proclamation of Independence, and in which Doña Josefa Ortiz de Dominguez took an active part. In 1821 it was besieged and taken by the Independents under Iturbide. At Querétaro, in March, 1848, the treaty of peace between Mexico and the United States was signed. Finally, in July, 1867, the Archduke Maximilian and his generals, Mejía and Miramón, were executed on the hill of Las Campanas, a few miles from the city,—a proceeding which completed the downfall of the empire which Louis Napoleon had attempted to establish in Mexico.

San Juan del Rio is a small city, 6500 feet above sea-level, and surrounded by good plantations irrigated from the river. It was a centre of traffic before the arrival of the railroad, and is still active in the commerce of cereals. Further on the plains and slopes are bounded by high mountains, such as the Galindo range on the west and the Santa Rosa to the southwest, at the base of which the town of Tequixquiapan is surrounded by large mesa-lands and hills, from which are extracted the famous Mexican opals, celebrated all over the world. The fertile and delightful valley is bounded on the north by the majestic peak of Bernal, a conical and almost inaccessible mountain, where the rough and extensive Sierra Gorda begins, through whose sinuosities and cañons of wild beauty rushes the Montezuma River, emptying into the Gulf through the paradise of Tampico.

In crossing the region of Arrovo Zarco, the railroad has to overcome new obstacles presented by the ruggedness of the country, either fertile or irrigated, or uncultivated, arid and rough, and sometimes presenting mountain slopes covered with extensive forests, which furnish fuel, railroad ties and lumber.

Through numerous curves and tortuous trails the railroad reaches Tula, the junction of the Pachuca branch, crossing the river of the same name. In the environments of the now decayed town, and on its hills covered with volcanic lava, are still found vestiges of one of the most ancient Toltec capitals, Tollán, of which the great priest and founder was the mysterious Quetzalcoatl, to whom are attributed magic powers, deep knowledge of truth, and the knowledge of the casting of metals and stonecutting. We are told that the city already flourished about 800 A. D. The present parochial church of Tula was constructed in the seventeenth century. Its turreted walls give it the appearance of a fortress.

The railroad follows the meanderings of the Tula, or winds through the hills

master-work of Enrico Martínez, the Tajo de Nochistongo, justly admired by all travellers, who can see it for a moment from the railroad, which runs along a few meters from the edge of the precipice built by the sweat of many Indians and the death of innumerable human victims, to save the City of Mexico from terrible and frequent inundations. That city is located in the interior of a vast basin, without outlet, into which descend the waters of the high mountains which surround it. These waters used to accumulate in large lakes with a very shallow average depth, and little higher than the average level of the city. On this account, frequent and terrible inundations resulted during the rainy season, and more than once almost completely destroyed the city.

Ever since 1580 radical measures have

A WAYSIDE STATION,—EL CASTILO, JUANACATLAN

covered with lava (which in some places shows columnar structures) until it again reaches the plain on leaving the station of El Salto. To the right is the Buautilán River, flowing over a bed of lava, spongy stone and volcanic ashes coming out at the portentous, artificial cañon,

been suggested from time to time, to save the city from such inundations. Indeed, in the time of the Indians there existed dikes to retain the water and retard its access to the old city of Tenoxtitlán. But in spite of these, any accident or washout was sufficient to cause

A FAIRLIE ENGINE ON THE VERA CRUZ LINE

alarm. From the beginning it was intended to give an outlet to the waters of the north of the basin, which were the most abundant, and which emptied into Zumpango lake,—principally the waters of the Cuautitlán River.

The project was entertained for many years in an embryo form, until, at the beginning of the seventeenth century, another plan was submitted by the able cosmographer of unknown nationality, Enrico Martinez. His idea was to open a tunnel through the hills and slopes of Nochistongo. In this, work was commenced in 1607, during the reign of Viceroy D. Luis de Velasco, by the employment of innumerable hungry and naked Indians at miserable wages. The tunnel advanced about three and one-half miles in less than two years, so that in May, 1609, the Viceroy, visiting the works, saw the waters of the Cuautitlán River running over the bed of the Tula. It was necessary to wall the tunnel with stone, and to make many repairs, to prevent or remedy its frequent obstruction. The plan was, in consequence, almost abandoned.

About 1616 the work was resumed upon it, but was shortly afterwards again suspended until 1625. In 1629 the tunnel was again cleaned out, and once more choked by the waters of Zumpango Lake, overflowing the city to a height of over 6 feet, drowning 3000 persons, and compelling the emigration of 20,000 families. The city remained inundated until 1631. Philip IV. ordered the abandonment of the City of Mexico and the rebuilding of it in a better location; but as the property was valued at that time at $50,000,000, it was finally decided not to give up such valuable interests.

In 1637 began the transformation of the old tunnel into the great and wonderful canal, constructed by the labour of hundreds of thousands of Indians, which has left to posterity one of the most gigantic works created by man, and which confers deserved glory upon Enrico Martinez. The gratitude of the city has erected a modest but eloquent monument to his memory.

At the railroad station of Huehuetoca the cañon of Nochistongo is only a few feet lower than the average level of the land; the sombreness of the landscape gives evidence of the poverty of the soil, limy in parts, volcanic in others; but further on it changes quickly in the surroundings of Cuautitlán, a village which,

like Huehuetoca, is in a complete state of ruin and decadence. They were lively towns before the railroad took from them the extraordinary traffic of the waggon road which crosses them, and placed the City of Mexico in close communication with the interior cities of the Republic. This waggon road appeared like a serpent of dust, and was remarkable in those days for the continuous traffic of carts, carriages, and all kinds of vehicles, pedestrians, companies of soldiers and bandits. To-day, destroyed, uncertain, and full of stones, it serves as a path to a few burros, patiently guided by their masters, and transporting fruits and other products of the neighbouring towns.

Tepotzotlán, a few miles from Cuautitlán, at the foot of the high hills which façade, but also in the splendid gilding of the altars of the temple. In the cloisters and chapels of the convent are a multitude of paintings. Perhaps the wooden sculptures, including especially the carving of an organ, and a small set of chairs of rich and delicate design, are more to be admired. A small chapel, adjoining the church, shows the same curious, extravagant style of architecture, resembling, in its variety and richness of color and profusion of figures, the ancient orthodox churches of the City of Mexico. This place is deserving of attention; but, unfortunately, is seldom visited.

Lechería is reached a little further on, almost at the foot of the eastern slope of the Guadalupe range, which enters the valley of Mexico, interrupting the

THE VERA CRUZ STATION IN MEXICO CITY

bound the horizon west of the railroad, has a magnificent convent and church, erected by the Jesuits before their first expulsion, and particularly noted for their beauty and good state of preservation, as well as for their curious, extravagant architecture, not only in the filigreed lines of a magnificent tower and plain and appearing to divide the southern portion of the valley.

The railroad here has to ascend the first incline of the range and wind up the hills to reach the top of the Cuesta de Barrientos of the old cart-road, from which can be admired the magnificent profiles and sinuous heights boundin

the valley of Mexico, and the extensive forests and vast fields of corn at the bottom of the valley, interspersed with groups of trees, among which, half concealed, are grouped the small villages over which tower high white spires. Finally, there may be discovered in the distance Chapultepec hill, with its castle, and at one side the massive black towers of the Cathedral and the blocks of houses, like walls of stone, which mark the site of the City of Mexico, the ancient capital of the vast Mexican Empire.

ANTICIPATIONS OF MODERN INVENTIONS BY MEN OF LETTERS

By James Johnston, A. T. S.

TO a remarkable degree numerous discoveries and inventions of the present day have been anticipated by imaginative writers. Illustrations of this class of discovery foretold, and even definitively indicated, may in some measure, therefore, moderate our self-laudation at the expense of the ancients. The student of letters may prove by quotations from the Bible, Homer, Lucretius, Dante, Shakespeare, Ben Jonson, Milton, Goethe, Tennyson, and others, notable forecasts of achievements realised in later years.

It has been remarked that the man of science subjects the phenomena of nature to rigid tests and experiments, and so endeavours to explain certain causes by definite principles. On the other hand, the poet, by a higher flight, through the faculty of imagination, mounts at once to the cause in which both phenomena and principle have their origin, and the same end, that of revelation, is attained by each through different modes of approach. In this unexpected form poetry and science find a common meeting ground.

Solomon, for example, who symbolically described the circulation of the blood nearly 3000 years earlier than Harvey's great discovery, is by no means the only old-world anticipant of truths which modern science has realised. Nothing is more "up to date" in the scientific world than the use of liquid air as a medium of research, though we need to be reminded that *liquidus aer* is frequently mentioned in the writings of Virgil. Equally interesting is Lucian's description of the inhabitants of the moon, seventeen centuries ago, as drinking "air squeezed or compressed into a goblet," where it formed a kind of dew.

More wonderful is Lucian's prediction, humorously narrated, in "Vera Historia," or "True Histories," written in the second century, of an aerial ship, the sails being inflated by a whirlwind, impelled through space to the moon, a dim forecast, it may be noted, of the air-ship of M. Santos Dumont, the intrepid Brazilian aeronaut. Before Lucian's sketch is set aside as a fable we glean that, as far back as 1709, a Brazilian priest applied to the king of Portugal for protection of his invention of a flying-ship, "by the help of which one may more speedily travel through Air than any other Way, either by Sea or Land, so that one may go 200 miles in 24 Hours; send Orders and Conclusions of Councils to Generals, in a manner, as soon as they are determined in private Cabinets, etc."

This strange craft, a diagram of which has been preserved, was provided with a pair of bellows for use when the wind failed, and also with a supply of "Large Amber Beads, which, by a Secret Operation, will help to keep the Ship afloat." It may be recalled here also that no less

a personage than Ben Jonson foreshadowed the Whitehead torpedo.

Again, various writers of antiquity seem to have been prognosticators of the marvellous epoch of electricity and its wonders, though all the ancients knew of it was the one fact of the action of amber, which they called "electron," when rubbed, upon light bodies. Thales (580 B. C.) thought a kind of soul dwelt in amber, and, three centuries following, Theophrastus wrote on the subject. Dove also cites the remarkable saying of a Chinese philosopher named Kuopho, in the beginning of the fourth Christian century, to the effect that "the magnet attracts iron as amber attracts small bodies." These were the ancient precursors of Dr. Gilbert, Queen Elizabeth's physician, and the father of modern electrical science, in whose hands, as one of the "Investigators of the Older Electricity," the subject was first expanded.

From his day we have journeyed far until that of the recent suggestion by Emperor William that German electricians and engineers should study the problem of making electricity the motive power in the fastest passenger mails, or the wonderful experiments conducted by Orling and Armstrong.

To Galileo, two centuries and a half ago, must be granted the credit of defining the electric telegraph in his "Systema Cosmicum"; while the lightning conductor was divined, if not put into operation, by the Etruscans long anterior to Franklin's day.

Probably the classical instance of intelligent anticipation of modern discovery is usually considered to be Dean Swift's description, in "Gulliver's Travels," of the discovery of two satellites of Mars by the Laputan astronomers. The celebrated dean, 175 years past, credited the astronomers of Laputa with discovering two satellites revolving about Mars, and, wonderful to state, the actual discovery of Mars' moons only occurred in 1877, when Professor Hall, of Washington, discovered the two tiny satellites of Mars. Swift wrote in his immortal work, "They have likewise discovered two lesser stars or satellites, which revolve about Mars, whereof the innermost is distant from the centre of the primary planet exactly three of his diameters, and the outermost five; the former revolves in the space of ten hours, and the latter in twenty-one and a half."

These figures have been generally regarded as indicating Swift's ignorance of, or contempt for, astronomy, and, likewise, the absolute improbability that a planet should have satellites revolving so swiftly that it should be possible to see two or three moon-rises and moon-sets within the compass of a working day. All analogy was said to be against it, yet the almost incredible scientific agreement of Professor Hall with Swift was so near "that some have refused to attribute it to coincidence, and assert that Swift must have had some uncanny means of knowing the truth by crystal-gazing, or astral currents, or one of the varied means of information which come within the ken of the Society for Psychical Research."

Romantic interest, consequently, entwines itself around the account of the satellites of Mars of which Swift wrote, and, — perhaps independently, — Voltaire, whereas it was only at the close of the last century that astronomers first saw these flying, miniature moons.

Next to this in celebrity among the more fascinating anticipations of scientific inventions is Strada's record of the wireless telegraph. The Italian's description of an efficient system of wireless telegraphy is familiar to the modern reader by Addison's quotation in the pages of the *Spectator*. The gifted Roman published his "Prolusiones" in 1617, where he portrays two friends carrying on their correspondence by the aid of "a certain loadstone, which had such virtue in it that if it touched two several needles, when one of the needles so touched began to move, the other, though at never so great a distance, moved at the same time and in the same manner." On this the comment is that each owner of a needle adjusted it to a dial plate with the letters of the alphabet disposed round its edge, in the fashion of an early form of electric telegraph which was superseded by the telephone.

When they wished to converse, one of them spelt out words, which were reproduced at any distance by the sympathetic needle of the other, "by which means they talked together across a whole continent, and conveyed their thoughts to one another in an instant over cities or mountains, seas or deserts."

This narration would certainly pass for an unscientific person's idea of the telegraph, and now that we have been taught in what fashion to dispense with the wires, it may, by and by, closely accord with facts.

As regards the invention of the telephone, it is astonishing to learn from the works of Robert Hooke, printed in 1664, that the telephone is not so modern an invention as is generally believed. Hooke says:—"And as glasses have highly promoted our seeing, so 'tis not improbable but that there may be found many mechanical inventors to improve our other senses, of hearing, smelling, tasting, touching. 'Tis not impossible to hear a whisper a furlong's distance, it having been already done; and perhaps the nature of the thing would not make it more impossible tho' that furlong should be ten times multiplied."

He continues:—"I can assure the reader that I have, by the help of a distended wire, propagated the sound to a very considerable distance in an instant, or with as seemingly quick a motion as that of light, at least, incomparably swifter than that, which at the same time was propagated through the air."

Hooke was an extraordinary inventive genius, and has justly been considered as the greatest of philosophical mechanics. The wonderful sagacity, nay, almost intuition, he showed in deducing correct general laws from meagre premises has probably never before or since been equalled. There was no important invention by any philosopher of that time which was not, in part, anticipated by Hooke. His theory of gravitation subsequently formed part of Newton's; he likewise anticipated the invention of the steam engine, and the discovery of the laws of the constrained motions of planets, in addition to which his own completed discoveries include the air-pump, the simplest theory of the arch, the balance spring of watches, and others.

Of Rabelais' story concerning the "frozen words" which startled Pantagruel and his happy crew on the voyage to the oracle of the Holy Bottle the world has long been familiar. Students of the great humourist maintain that the narrative of the "frozen words" must be taken to imply that their author had something akin to a prophetic vision of the phonograph.

In another direction it now appears that Rabelais played the seer and still nearer approached to a recent invention of unique creation. This relates to the "moving platform," a leading attraction at the Paris Exhibition in 1900, by which a passenger stepped on to a travelling road, or path, and was carried to his destination without further effort. If some features of this may be traced, by anticipation, to the mind of the old sage who defined rivers as "roads that travel," the real precedent is discoverable in the fifth book of Rabelais' series of masterpieces.

Rabelais, in the exuberance of his imagination concerning the Isle of Odes, where the roads travel of themselves, depicts Pantagruel and his gay mariners voyaging to the oracle of the Dive Bouteille, on the island of Odes. The term "odes," in spite of its associations, has nothing to do with poetry. On this pleasant isle where the roads travel of themselves, and thus (according to Aristotle's definition), must be classed as animals of locomotion, the traveller had simply to enquire his way of the road which was going to his destination, to get upon it, and so be carried, without further trouble, to the place he desired, "just as happens to those who take passage from Lyons down the Rhone to Avignon and Arles."

Who forgets that Mark Twain, some years back, amusingly propounded a similar fancy when he took passage (by slow freight) on a Swiss glacier?

At the present hour the travelling road or path is under experiment in the suburbs of Paris, and is possibly des-

tined some day to supersede omnibuses and tramways.

In the light of these facts it seems hard that Friar Roger Bacon, the student of science before the scientific period, who predicted that one day carriages would move without horses, and ships cross the ocean without sails, should be laughed to scorn as an addle-brained monk, whom much learning had made mad.

Another prophecy, significant and weighty, may be seen in the Marquis of Worcester's "Century of Inventions," issued in 1655, with its amazing list of forecasts of telegraphs, steam engines, flying and calculating machines (the latter antedating Babbage's marvellous creation), dynamite shells and torpedoes, ironclads, quick-firing guns, and revolvers. And, again, the many-sided genius of Lord Bacon predicts, in the "New Atlantic," submarine boats, as well as "some degrees of flying in the air."

Similarly, the poet Drummond, in 1626, indicates, in very precise language, some of the most powerful naval and military weapons of the present day, for which he then obtained letters patent.

In relation to pathology and medical science, the illustrious Dutchman, Leeuwenhoek, made amazing researches into specimens of bacteria and minutely described these upwards of two centuries ago. History, with a knack of repeating itself, shows, in the annals of zymotic diseases, that the reputed discoverer of a new fact or idea is probably never the first to have made the discovery, or even to have formulated it. In the world of ideas, as in that of material, a continuity can be perceived by which new ideas are evolved from old ones.

It was not a surprise to notice that M. Pasteur's claim to have discovered that zymotic diseases are due to germs was challenged. Over a century and a half ago Dr. Goiffon wrote a work on the origin of the plague, wherein he advanced the theory that the disease was dependent on minute insects or worms which had none the less an existence though they were then beyond the powers of the microscope to reveal. The learned investigator had likewise something to say on the process of infection, which he considered to be the work of minute living creatures that conveyed infection in a latent condition from one place, to break out afresh in another. The question has, however, been asked, Did not Goiffon get the idea from some still more ancient master?

The last example in this fertile and suggestive field is garnered from the pages of the world's immortal dramatist, Shakespeare, who, in "Troilus and Cressida," was an anticipant, by a century, of Sir Isaac Newton's illustrious and far-reaching discovery,—the law of gravitation.

NICKEL-STEEL

ITS PRACTICAL DEVELOPMENT IN THE UNITED STATES

By H. F. J. Porter

MAN is never satisfied to leave well enough alone, and this propensity to try to improve matters, although the basis of the world's advance, has seldom brought him either pleasure or profit at all commensurate with his individual outlay of time and money. Man's efforts are directed towards extending and making permanent the broad highway along which the car of progress may proceed to its ultimate destination, but his work is generally so far in advance of its time that his span of life is exceeded before the car reaches him, and therefore few have been so fortunate as to secure a seat in it as it rolls along on its triumphal journey.

Rather has history been replete with instances of wrecks of lives and fortunes devoted to pioneering excursions over unbeaten paths in search of better materials and methods of construction than those already in use. Especially is this true of ventures into the unknown realm of metallurgy in attempts to obtain a stronger and cheaper metal to meet the increasing severity of industrial demands. An inborn prescience of the enormous commercial value of the ideal metal to posterity has led men to risk all in the effort to secure the reward of success.

Of the various attempts to combine some element with iron, this being the most abundantly attainable and easily worked of all the metals, and thus produce an alloy superior to steel, none has been as successful in developing anything which shows as wide and varied adaptability to our requirements as those which brought nickel-steel into existence, and yet this metal, although known to metallurgists for many years, has only of late come forward with any great rapidity to take a prominent place in the trades. Commercial demands do not seem to have until recently required a material of which the physical qualities were as high as those possessed by this alloy. It is, in fact, more than three-quarters of a century since it was brought out, and its projectors passed away long before its merits attained any recognition in the commercial world. And it has been only by the continued insistence of the metallurgist and through intelligent trial by engineers of the widest knowledge and experience that this metal has obtained a place in the trades and finally come into service in its special field.

We must go as far back as 1820 for the first recorded experiments in the direction of a nickel-iron alloy. Mr. Henry Hadfield, in a paper read before the Institution of Civil Engineers of Great Britain, says that in that year Michael Faraday, working with Stoddart, of Sheffield, England, produced the first specimen of nickel-steel. Faraday probably took up this subject because his attention had been drawn to the numerous experiments of Beyman and Richter with nickel about the beginning of the century, and also from the fact that he was aware that meteoric iron contains nickel, and knew of the strong affinity of iron for this metal. Mr. George F. Kunz, special agent of the United States

Geological Survey, in a private communication to the writer, says:—

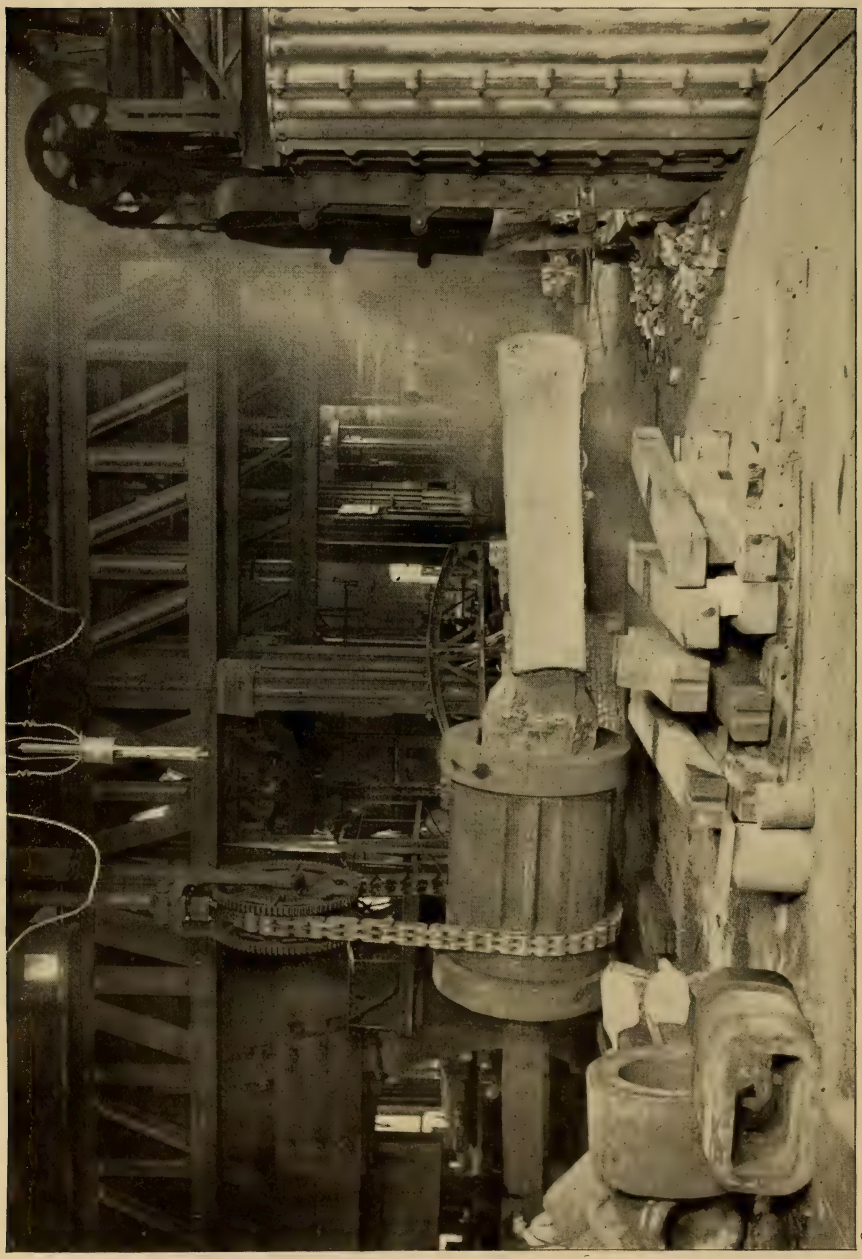
"Of meteorites we have about 550 'falls' and 'finds.' By 'falls' is meant when a meteor has been seen to fall; by 'finds' when the mass is found and scientifically proven to be undoubtedly of meteoric origin. I doubt if there are five recorded 'falls' or 'finds' in which iron is not present, and invariably, when it is present, there is nickel with it, and usually as a pure metallic alloy. More than one-half of these meteorites are iron containing from 9 per cent. to 11 per cent. of nickel. In a few exceptional cases as high as 40 per cent. of nickel is recorded."

Berthier, in France, is reported to have also carried out nickel-iron alloy experiments at a little later date than Faraday, but the results of his work do not seem to have been preserved. Mr. R. Fechner mentions, in a paper on "Nickel Mining and Smelting" in the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, that Hofrath von Gersdorff, in 1824, applied nickel to iron for industrial purposes. Prof. Otto Vogel, in a very carefully prepared article in *Stahl und Eisen*, 1895, states that Mr. Wolf, a German manufacturer, of Schweinfurt, was the first to utilise nickel-steel commercially, and an interesting confirmation of this is given by Dr. Justus von Liebig in the *Annalen der Pharmacie*, in 1832, in which he states that Mr. Wolf combined nickel and iron in perfectly ductile alloys which could "be readily damascened." It was then brought into the market as "meteoric steel," though no details are given of its composition. No proof is available, however, that any demand was created for the material.

Dr. W. L. Austin, in the *Berg und Hüttenmännische Zeitung*, in 1894, states that nickel-iron appeared for the first time in large quantities at the New York Exhibition of 1853, Mr. Philip Thurber having produced it from nickeliferous limonite from Marquette, Mich. Little, however, appears to have developed in this direction until a much later date, or about 1870, when Mr. Alexander Parks, of Birmingham, England, took out several patents for the production of alloys of iron and nickel; but it would seem that very little was done in a practical way with them. In the same year Prof. Nordenskjold discovered iron in its native state in small, detached masses on islands in Davis Straits. It was associated with 2 to 3 per cent. of nickel, thus resembling meteoric iron.

ONE OF A LARGE NUMBER OF NICKEL-STEEL FIELD RINGS FORGED WITHOUT A WELD AT THE BETHLEHEM STEEL WORKS, FOR 5000 H. P. GENERATORS, AT THE NIAGARA FALLS POWER PLANT. DIAMETER, 11 FEET 7⅜ INCHES; WIDTH, 4 FEET 2¾ INCHES; WEIGHT, 28,840 LBS.

Interest in the application of nickel to iron alloys appears, then, to have slept for about ten years, one reason



A 75-TON NICKEL-STEEL INGOT COMING FROM THE HEATING FURNACE AT THE BETHLEHEM STEEL COMPANY'S WORKS

for this delay having possibly been the difficulty in obtaining satisfactory nickel metal. Mr. Fleitmann, of the Iserlohn Works, Germany, made, therefore, a considerable step forward when he improved the metal itself by the addition of a small amount of manganese, enabling soundness and malleability, amongst other qualities, to be obtained.

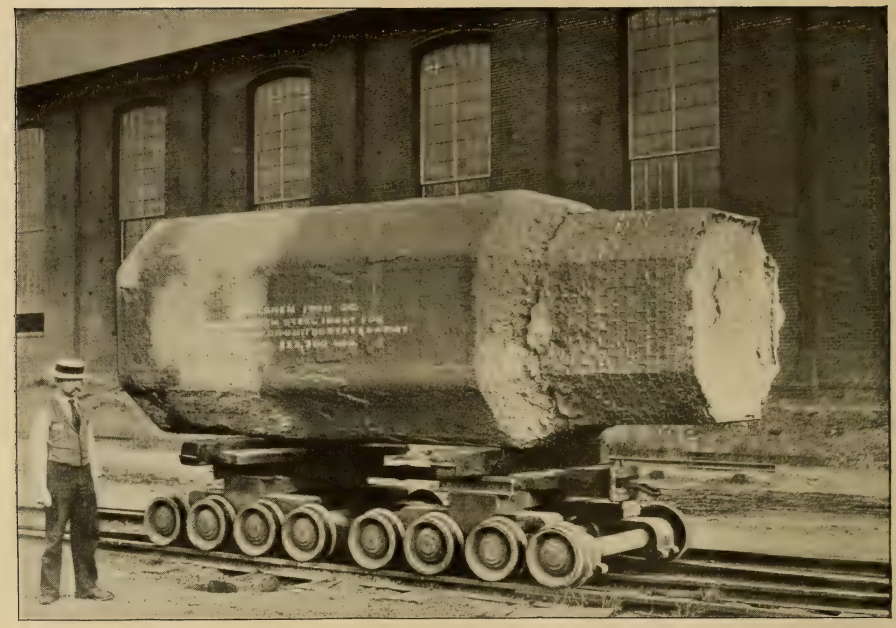
But already events were taking place which were destined soon to bring nickel-steel into the glare of the flash-light turned towards it by the United States Government. In the early eighties the enlightened nations of the world began to vie with one another in equipping themselves with improved enginery for naval warfare. The foremost nations of the Old World were already supplied with large fleets of war vessels, many of which were sheathed with wrought-iron plates of varying thickness. The United States, however, was not only without a navy, but destitute of an ordnance plant fitted for making either armour-plate or guns.

Rear-Admiral Robley D. Evans, in an address before the Railway Master Mechanics' Association, in June, 1899, said:—"In 1882 I had the good fortune to be ordered as a member of what is known as the first advisory board for rebuilding the navy. It was an awfully hot summer, and fifteen of us rather impatient spirits got together in Washington, presided over by Admiral John Rogers. When we looked the field over we found that we had no navy at all; we were hopelessly behind the age, and it seemed hardly worth while to rebuild our navy. I shall never forget, as long as I live, the trouble I caused in that small convention by proposing that we should build steel ships. I was the original steel man, and when I proposed that all ships in the future should be built of steel, Admiral Rogers adjourned the board for three weeks to prevent a fight."

The animosity referred to was due to a strong prejudice which existed at the time against steel, owing to the fact that, being a new material, proper methods of manufacturing it were not generally understood, and the resultant product, as placed upon the market, was not uniformly good. The impression, therefore, had rapidly gained ground among the uninformed that the metal was intrinsically unsatisfactory. But there were some manufacturers who, having given the subject careful study, had equipped themselves properly, and by the application of scientific methods of manufacture were able to produce a highly satisfactory quality of steel. In the hands of these men steel guns had reached a high state of perfection, and these, in connection with improved projectiles, also made of steel, had caused wrought iron armour-plate to be acknowledged as incapable of resisting the increased power of penetration. In the search for a new material for armour-plate the results of the past investigation of the metallurgist were reviewed and his resources were called upon in the hope of producing an alloy of steel that would satisfactorily meet the requirements which the service, constantly becoming more severe, demanded.

In 1884 the experiments of M. Marbeau, of the Société Ferro-Nickel, at Lizy-sur-Orcq, in France, attracted considerable attention, and in 1888, at Moutalair and at Imphy, these experiments were extended, and later were continued by M. Worth at the works of Schneider et Cie, at Le Creusot. In 1889 Mr. James Riley presented, before the Iron and Steel Institute, the first paper of real value on the subject, and gave the results of an extended series of tests made on nickel-steel having various percentages of nickel in its composition.

This may be considered as the first authoritative record of tests by a scientist of recognised ability as to the possibilities of nickel-steel. His deductions were considered of so much importance to the commercial world that he was at once employed by a syndicate of capitalists to continue the work. The latter were subsequently induced to take tentative steps towards obtaining control of the nickel supply of the world. In fact, Mr. Riley was censured for having prematurely made public his conclu-



A NICKEL-STEEL INGOT FOR THE 16-INCH TUBE OF A 126-TON GUN. TOTAL LENGTH, INCLUDING SINK-HEAD, 16 FEET 7 INCHES; DIAMETER, 6 FEET 2 INCHES; WEIGHT, 99.2 GROSS TONS

sions instead of bringing them to the attention of those whose business it was to take advantage of such opportunities for creating monopolies.

The reported efforts to secure the available nickel mines caused the United States Government to take immediate steps to protect itself, and Congress at once gave to the Secretary of the Navy a grant of $1,000,000, to be expended at his discretion in the purchase of nickel oxide. Such confidence in the business capacity, honesty and integrity of one man has never been given to any Secretary by the American Government except in time of war. From that time on until 1898 all nickel used in the armour of United States naval vessels was furnished by the government to the manufacturers, in the form of nickel oxide, which contains about 77 per cent. of pure nickel.

Up to this time the compound plates, composed of a steel face and iron backing, made by John Brown & Co. and Charles Cammel & Co., of Sheffield, England, and the "all-steel" plates of Vickers & Co., were competing for supremacy as a protective sheathing for war vessels. The "compound" plate consisted of a face of hard, but not necessarily hardened, steel, welded to a tough wrought-iron back. The steel face was about one-third the thickness of the whole plate, and its effect was to offer resistance to penetration of the shot and produce a breaking effect on the latter, while the tough iron prevented the plate from cracking to fragments and falling away piecemeal from the structure it was intended to protect. The homogeneous "all-steel" plate claimed, by means of its hardness and toughness, to break and stop the projectile and yet remain in good shape upon its backing.

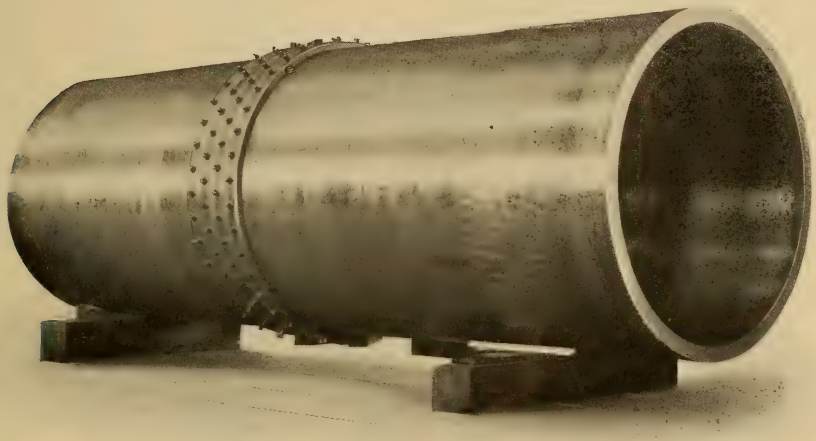
The armour-piercing shell, however, came about, and both "compound" and "all-steel" plates were overmatched; the "compound" plate was penetrated and the "all-steel" plate cracked and broken by a shell that had attained such excellence as to be almost undeformed by impact.

The investigations into the properties of nickel-steel at the works of Schneider

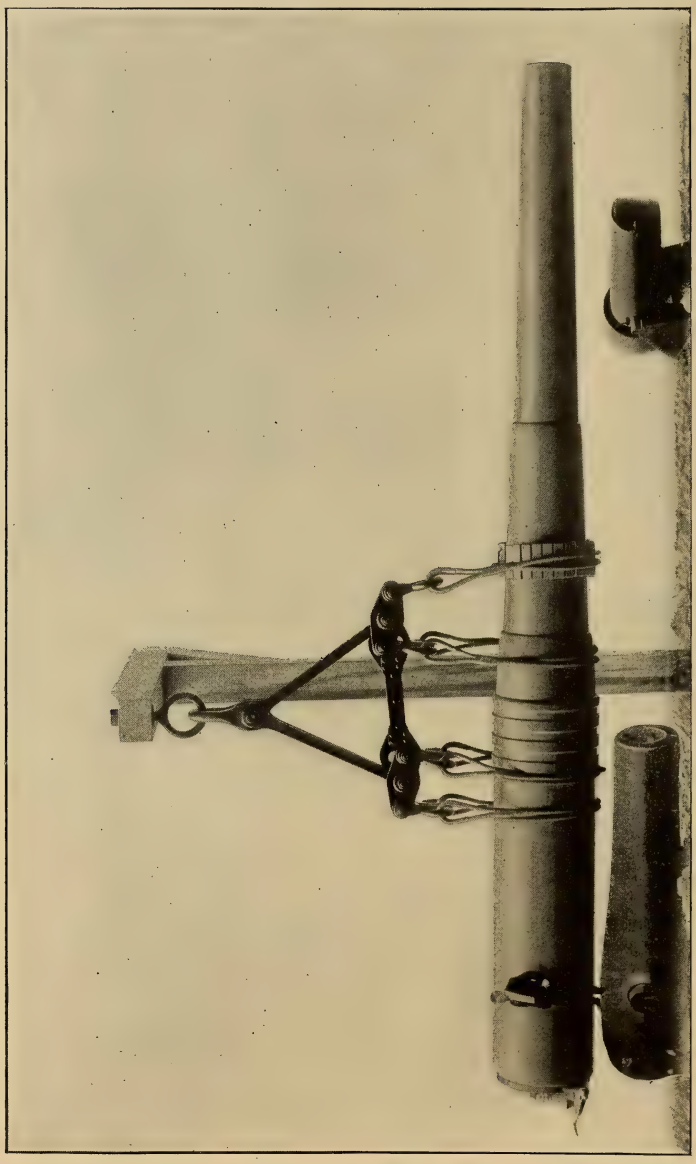
et Cie., above referred to, resulted in the development of armour-plate possessing remarkable projectile-breaking qualities, combined with great tenacity and resistance. The metal from which it was made was an alloy of nickel and steel containing 3 per cent. of nickel. Experiments showed its possibilities and good qualities in the first plates tested, and in 1889-1890 the armour-plate of nickel-steel had reached such a state of development that its existence could not be overlooked by a government seeking the best type of armour for its battleships.

In response to the invitation for a competitive trial of armour-plates, extended by the Navy Department at Washington to foreign armour makers (for as yet there was no plant in the United States capable of producing a plate of the required thickness), three plates were submitted for test at Annapolis, Md., in the summer of 1890. These plates were all of the same size, 6 ft. × 8 ft. × 10½ in. in thickness. One was a "compound" plate from the works of Cammel & Co., of Sheffield, England, and the other two were respectively "all-steel" and "nickel-steel" plates from Schneider et Cie. The three leading types of armour of most recent development and approved type were thus represented. Each plate was submitted to four rounds from a 6-inch gun firing Holtzer steel shell, with a striking velocity of 2075 feet per second, and then to one round from an 8-inch gun firing Firth steel shell, with a striking velocity of 1850 feet per second. These velocities were calculated to drive the shell just through a good homogeneous steel plate.

The "compound" plate was completely penetrated by all projectiles fired at it and its steel face was destroyed, the weld between the hard face and the soft backing being its weak point. The "all-steel" plate kept out all shots fired against it, but it was badly cracked at its centre by the last round from the 8-inch gun. The resistance obtained from the "nickel-steel" plate far exceeded all expectations. At the fifth shot, with a striking energy of 4988 foot-tons, the 8-inch armour-piercing projectile broke into many pieces without developing in the plate a sign of a crack. Never before in the history of armour had a plate given results to compare



OIL TEMPERED NICKEL-STEEL AMMUNITION TUBE FOR ONE OF THE 8-INCH TURRETS OF THE U. S. BATTLESHIP "IOWA." FORGED HOLLOW IN TWO LENGTHS, WHICH ARE JOINED BY A SPLICE BAND. OUTSIDE DIAMETER, 62½ INCHES; INSIDE DIAMETER, 57 INCHES; LENGTH, 15 FEET; WEIGHT, 27,200 LBS MADE BY THE BETHLEHEM STEEL COMPANY



20-inch Rodman Smooth Bore.
Weight, 116,000 lbs. Projectile,
Round Shot, 1000 lbs.

10-inch Parrott Rifle.
Weight, 26,000 lbs.
Projectile, 300 lbs.

THE U. S. ARMY 16-INCH RIFLE. WEIGHT, 358,400 LBS.; PROJECTILE, 2370 LBS.

THE NICKEL-STEEL FORGINGS FOR THIS GUN WERE SUPPLIED BY THE BETHLEHEM STEEL COMPANY

with this, withstanding a total energy of 16,940 foot-tons without developing a single crack and without being perforated.

Meanwhile, the American Advisory Board, of which Rear-Admiral Evans was a member, had departed on a visit to the great gun and armour-plate plants of Great Britain and the Continent for the purpose of obtaining information to embody, in the shape of intelligent recommendations, in a report to the Secretary of the Navy, as to the establishment of an ordnance works in the United States, either under government or private ownership. On its return home it was made public that through the skilful efforts of its secretary, Lieutenant W. H. Jaques, the personal objections of Sir Joseph Whitworth, of Manchester, England, to the uses of his special forging appliances in other works, had been overcome and that the United States Government was prepared to encourage enterprising capital to establish a modern ordnance works.

Accepting the far-sighted recommendations of its superintendent, Mr. John Fritz, the Bethlehem Iron Company at once opened negotiations with Whitworth & Co. whereby the entire forging plant of the latter would be duplicated at their works in South Bethlehem, Pa., and immediately afterwards a similar contract was concluded with Schneider et Cie. by which their armour-plate patents and special machinery were purchased. The money value of these contracts was very great, and up to that time had never been exceeded by that of any single order given by a private firm.

When this plant was equipped for work, it at once began the manufacture of armour-plate for the Navy and guns for both the Army and Navy. Advantage was taken of all the improvements in methods of manufacture which had come about during the building of the plant, and among these was a process of case-hardening the exterior surface of armour-plate which was perfected by the late H. A. Harvey, at the works of the Bethlehem Steel Co. By means of this the carbon element in the composition of the metal diminished from about 1 per cent. at its surface until, at a depth of about 2½ inches, the original amount of 0.25 per cent. was obtained

Such plates could be oil or water-hardened, annealed or subjected to any other treatment desired, and thus in one plate the advantages of a hard face, combined with a tough back previously secured in a "compound" plate, were obtained. In the fall of 1891 nickel-steel plates of this type were presented for test by the Bethlehem Iron Company at the United States Government Proving Ground, at Indian Head, Md., and showed themselves to be so far superior to those put forward the year previous by British and Continental armour-plate makers that the United States Government adopted them at once, and by becoming the first nation in the world to take this important step, became the pioneer in giving nickel-steel prominence in the metallurgical and commercial field. Its adoption for armour-plate by the United States led to its favourable consideration by all the great powers, and at the present time nickel-steel is used in part or exclusively as a protective casting on nearly all modern war vessels, wherever constructed.

The members of the Ordnance Bureau of the Army showed their confidence in the tests, to which they themselves subjected the new metal, together with deductions drawn from the experience of the Navy, by recommending in 1898 the adoption of nickel-steel as the material from which the largest gun ever designed should be made. This gun, which is now being assembled at Watervliet Arsenal, is 16 inches inside diameter, 49 feet 2.9 inches long, and, when completed, will weigh 358,400 pounds. In the construction of this gun the size of some of the component parts was so enormous that ingots larger than any previously cast were required to make them, the largest weighing more than 111 tons.

The remarkable toughness exhibited by nickel-steel in its resistance to penetration of shells and shown by its high physical properties of ultimate strength,

elastic limit, elongation, and reduction of area in tensile test pieces, led engineers and metallurgists to suggest its use for commercial forgings, and especially those of which, like piston-rods of steam hammers and rock drills, the service consists of a series of shocks, or, in crank and crosshead pins and axles and shafts, where the rapidity of alternating stresses to which they are subjected has the same effect as a series of shocks.

That iron and steel crystallised from shock or rapid alternation of stress had already been shown to be a delusion through tests made on special machines in the laboratories of German and British engineers and the United States Government Testing Bureau at Watertown, Mass. These machines served the further purpose of comparing the ability of different metals to resist so-called "fatigue," *i. e.*, their relative powers of endurance in a special service. Tests made at Watertown on bars of wrought iron and steel sent there by various manufacturers, and of nickel-steel from the Bethlehem Iron Company, gave the results in Table I., and set at rest all doubt that this new metal was the nearest approach to the ideal metal for forgings so far put forward.

That the Bethlehem Iron Company had the courage of their convictions in regard to nickel-steel the following incident will show. It gives further evidence also of their progressiveness after being assured that they were right. In the development of their plant the largest steam hammer in the world had been installed. Its capacity was 125 tons of falling weight. The piston-rod of this hammer was made of medium-high-carbon open-hearth steel, having a diameter of 16 inches and with a 4-inch hole running through its centre. This rod failed by bending, and, with the imperfect knowledge then existing of the service of various qualities of steel, and burdened by an inability to break away from the traditional impression that the harder the steel, the greater would be its tendency to crystallise and so fail in service, lower-carbon steel was resorted to for the replacing rod, in the hope that it would resist shock better and remain in service longer.

This supposition, of course, proved to be erroneous, and the second rod failed after a shorter service than the first, and its failure was much more serious. About this time the advantages of nickel-steel for service of this kind became known through the tests made at Watertown, and the third rod was made of this metal. Its dimensions were changed somewhat; the outside diameter was increased to 17 inches, and the hole was made 8 inches in diameter for more than half its length and the balance 7 inches in diameter. This rod fulfilled all expectations.

Progressive manufacturers who use many steam hammers in turning out their product have found, from actual trials in their works, that this material is better suited to their service than any other, and have adopted it permanently as the best metal from which to make their piston-rods.

Analysing the results of various and many investigations, experiments and tests that have been made in order to obtain scientific deductions on which to base consistent methods of manufacturing different grades of nickel-steel suitable for the requirements of varied service, it is found that the remarkable properties of this alloy are imparted to it through the peculiar effect that the nickel has on the carbon contained in the steel. We understand that in the cooling of carbon steel from the fluid state the iron crystallises out of the mother liquor, and from the latter a carbide of iron cement is formed which surrounds the iron crystals and binds them together, and so the amount of carbon in the composition of the steel has much to do with the physical properties of the metal, this element causing a peculiar hardening effect, especially under the influence of water or oil-tempering. Now with iron, practically pure, or containing only a very small amount of carbon, nickel forms a homogeneous alloy much tougher and stronger than either nickel or iron alone, each 1 per cent. of nickel up to

TABLE I.

Under a fiber stress of	40,000	lbs. per square inch
Wrought iron breaks after	59,000	alternations of stress
0.15 per cent carbon steel breaks after	170,000	" "
0.25 per cent carbon steel breaks after	220,000	" "
0.35 per cent carbon steel breaks after	317,000	" "
0.45 per cent carbon steel breaks after	976,000	" "
3¼ per cent nickel steel, carbon 0.25 to 0.30 per cent	1,850,000	" "
4½ per cent nickel steel, carbon 0.25 to 0.30 per cent	2,360,000	" "
5½ per cent nickel steel, carbon 0.25 to 0.30 per cent	4,370,000	" "

5 per cent. causing an increase of about 5000 pounds in elastic limit and 4000 pounds in tensile strength.

The effect of nickel upon the resultant metal as the percentage of carbon increases varies within limits in accordance with the amount of the latter in the alloy. In nickel-steel possessing less than 0.25 per cent. of carbon a small amount of nickel up to 1 per cent. does not seem to unite with the carbon, but remains separate from it, acting as a foreign element, and, therefore, as a source of weakness. Above this amount, and up to 8 per cent., nickel not only unites with the carbon, intensifying its hardening effect, but combines also with the iron itself, increasing its toughness and ductility. As the amount of nickel increases above this point its tendency is more in the direction of throwing the carbon into the state of graphite, under which condition the steel becomes less susceptible to the effect of water or oil-tempering, and at about 20 per cent. of nickel the effect of the carbon element is neutralised.

A range, therefore, of from 3 to 6 per cent. is found to be best adapted for general service, the toughness and strength of the crystalline compound of nickel and iron being very great, and the highest sensitiveness to heat treatment being thus attained through the effect of nickel on the carbon element. As steel in its molten state is governed by the same laws as other liquid solutions, so in its normal state it is regarded a "solid solution," and the same laws are applied to it. As in any liquid, the greater the amount of foreign matter held in solution, the lower will be its boiling and freezing points. So with steel, the more carbon it contains, the lower is its melting point as well as its other critical temperatures, and the addition of nickel still further lowers these temperatures, and, within certain limits, makes the resultant alloy more sensitive to mechanical and heat treatment. The temperature known as the recalescent point, used in the annealing and tempering processes, is about 1600° F. for 0.25 carbon steel and about 1400° F. for 0.50 carbon steel, while that of 0.25 carbon steel with 5 per cent. nickel is about 1100° F., and of 0.50 carbon steel with the same amount of nickel is about 900° F. It is evident, therefore, that great care and a full understanding of the composition of the metal must be exercised in its manipulation or it can very easily be ruined by overheating as well as by working it at low temperatures.

Annealing lowers to a slight extent the elastic limit as compared to the tensile strength, and quenching in oil or water uniformly restores this property. With proper care, however, very uniform and satisfactory results will be obtained. The influences of nickel on both elastic limit and ultimate strength increase with the percentage of carbon, The ratio of gain due to 1 per cent. of nickel are shown in the diagram prepared by D. H. Brown, of Cleveland, and given on page 491.

Nickel-steels show an increase in elongation and contraction of area when compared with simple steels of the same tensile strength. A steel having 0.25 per cent. carbon and 3 per cent. nickel is equivalent to a 0.40 per cent. carbon steel in tensile strength, while the elastic limit and elongation are higher. In steels of less than 0.50 per cent. carbon the elastic limit is about 50 per cent. of the ultimate strength, and usually less than this when properly annealed. Nickel raises the proportion about 5 per cent. for each 1 per cent. of nickel added.

Nickel-steel for commercial uses (3 to 6 per cent.) is not hard when properly annealed, but is exceedingly tough,

NICKEL-STEEL CONNING TOWER OF U. S. BATTLESHIP "BROOKLYN." OUTSIDE DIAMETER 7 FEET 11¾ INCHES; 8⅝ INCHES THICK; 9 FEET 11 INCHES LONG; WEIGHT 77,600 LBS.

the nickel seeming to impart some of its own properties to the alloy. In colour it is lighter than simple steel of the same carbon, and when polished has the appearance of being nickel-plated. The corrodibility of nickel-steel lessens as the amount of nickel in its composition increases. Low percentages of nickel affect this property slightly; high percentages, however, above 18 per cent., tend to produce an alloy which is practically non-corrosive.

The conspicuous superiority of nickel-steel over carbon-steel in resisting alternating stresses impressed the engineers in charge of the construction of the new vessels of the United States Navy with the peculiar fitness of this metal for the severe service required of such marine engine forgings as shafts, crank and crosshead pins, piston and connecting rods; and specifications were at once drawn calling for materia having such high physical qualities as could be obtained only in this metal and through its production, under the most approved methods of fluid compression, hydraulic forging hollow on a mandril, oil-tempering, and annealing.

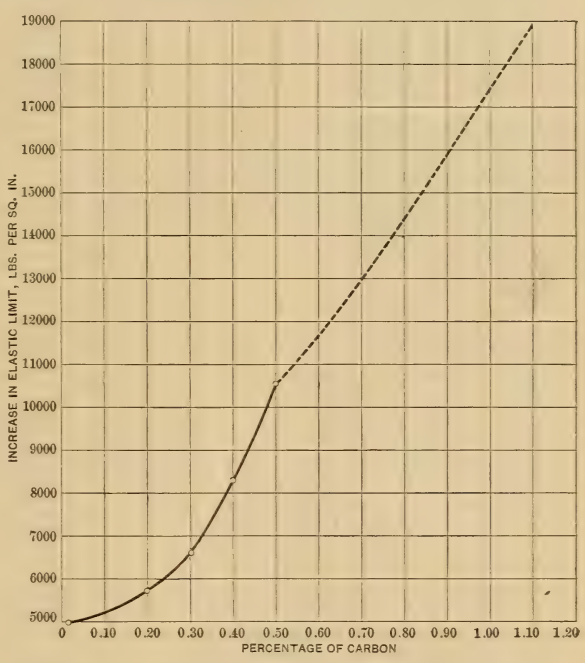
The two nickel-steel propeller shafts of the cruiser *Brooklyn*, made at this time, will give an idea of what was then used. These shafts had an outside diameter of 17 inches, an axial hole of 11 inches, and were 38 feet 11⅜ inches long.

In a paper presented before the Society of Naval Architects and Marine Engineers, Mr. R. W. Davenport, vice-president of the Bethlehem Iron Company, stated that Professor Mansfield Merriman, of the department of civil engineering at Lehigh University, had estimated for him the strength of these

shafts compared with solid shafts of the same sectional area made of medium carbon steel when strained to one-half of their elastic limit, as given in Table II, the elastic limit of the *Brooklyn* shafts being assumed to be 50,000 pounds per square inch and that of the carbon steel shafts, 30,000 pounds per square inch.

From this table it will be seen that by the use of hollow shafts made of nickel steel, having an elastic limit of 50,000 pounds per square inch, there is a gain in strength of three to one, and a reduction in weight of more than one-half, as compared with solid carbon steel shafts of equal weight and equal strength, respectively. In point of fact, however, the physical properties of the metal from which these shafts were made proved to be as follows:—Tensile strength, 94,245 pounds per square inch; elastic limit, 60,770 pounds per square inch; elongation, 25.55 per cent.; and reduction of area, 60.38 per cent., all in test specimens ½ inch in diameter and 2 inches long between gauge marks and taken from full-sized prolongations on one of the ends of the forgings. Had this higher figure for the elastic limit been used in the above calculations, Prof. Merriman's comparison would have been more striking.

So also in the case of the shafts for the torpedo-boats built at this time by the Herreschoff Manufacturing Company, of Bristol, R. I., the possible reduction of weight by the use of this steel was demonstrated. It was first proposed to adopt high-carbon steel with an elastic limit of about 50,000 pounds per square inch for these shafts, their small size (6 inches diameter) permitting this high-grade material to be used. It was estimated, however, that by the use of nickel-steel shafts of this diameter could be bored with a 4.16-inch hole and could be oil-tempered, and that thus a material possessing an elastic limit of 65,000 pounds per square inch could be obtained. Thus the weight would be reduced one-half, without reducing the torsional strength. The shafts were so made, and test bars from their ends gave a tensile strength of 101,000 pounds per square inch; elastic limit, 68,700 pounds per square inch; elongation, 22.12 per cent., showing that by the substitution the results expected had been exceeded.



APPROXIMATE CURVE OF INCREASE IN ELASTIC LIMIT, DUE TO ONE PER CENT. OF NICKEL

Since that time the satisfactory service which these nickel-steel forgings have continued to render has led the Bureau of Construction of the United States Navy to direct that all their principal forgings shall be furnished under specifications which can be met only by the use of nickel-steel properly manufactured, as follows:—

High-Grade Machinery Forgings.—To have a tensile strength of not less than 95,000 pounds, elastic limit not less than 65,000 pounds, elongation not less than 21 per cent. in two inches Oil-tempered and annealed. Used for main engine shafting, crosshead pins, connecting-rods, piston-rods, tie-rods, valve-stems, links, eccentric-rods, etc., with their bolts, nuts, keys, feathers, etc.

For the more unimportant forgings either nickel-steel or carbon steel may be used, at the option of the manufacturer, as follows:—

Class A, No. 1 Machinery Forgings.—To have a tensile strength of not less than 80,000 pounds, elastic limit not less than 50,000 pounds, elongation not less than 25 per cent. in two inches. Oil-tempered and annealed or not, at option of manufacturer. Used for columns and other stationary parts of the main engines.

bending to which they are subjected by the superimposed weight and the vibration attendant upon the striking of the paddles upon the water. These shafts used to be made of wrought iron, and their frequent breaks were the cause of much loss of life and property.

An improvement upon this practice was made in the substitution, about

TABLE II.—COMPARISON OF THREE STEEL SHAFTS

	Propeller Shaft U. S. S. "Brooklyn" Hollow	Solid Shaft Same (Approximate) Sectional Area	Solid Shaft of Same Strength Under Applied Loads or Horse-Powers
	Outs. Diam. 17" Ins. Diam. 11" Nickel Steel, E. L. 50,000 lbs. Per sq. in.	Diameter 13" Carbon Steel, E. L. 30,000 lbs. Per sq. in.	Diam. 18.90" Carbon Steel, E. L. 30,000 lbs. Per sq. in.
Areas, of sections, square inch	131.95	132.73	280.55
Weights per yard, pounds	1,346	1,354	2,801
Comparative strengths under applied loads in flexure or under applied horse-powers in torsion	307	100	307
Load, in pounds, at middle of a span of 12 feet on two supports, which strains to one-half elastic limit	276,200	89,900	276,209
Length of beam on two supports which is strained by its own weight to one-half elastic limit	121′ 6"	77′ 6"	83′ 4"
Horse-powers transmitted at fifty revolutions per minute when strained to one-half elastic limit	15,780	5,130	15,780

Meanwhile, not only have other nations also adopted this material for the marine engine forgings of their navies, but representative marine engineers all over the world have introduced it for the forgings of great transoceanic liners, as well as of high-grade yachts, in which lightness and strength are required, and where the owners of these vessels are willing to invest a little more than they otherwise would pay for forgings made of ordinary materials, looking upon such investment in the nature of insurance against accident from breakage.

On the system of rivers which bisects the United States there plies a peculiar type of vessel termed the stern-wheel steamer, which, although not of as great importance as a means of transportation in the Central West at the present time as it was before the railway became its competitor, still figures as a prominent feature on the rivers between the cities of St. Paul and New Orleans and Pittsburgh and Kansas City. The shafts of these steamers, overhanging at the stern and supporting there a large paddle-wheel, must be not only as light as possible, but very strong, in order to resist the

twenty years ago, by Fried. Krupp, of Essen, Germany, of crucible steel shafts of the same diameter, but bored and oil-tempered. These shafts, although lighter, were no stiffer than those they replaced, and, therefore, bending as much, they broke under the severe service to which they were subjected. Hollow-forged shafts of nickel-steel are now taking their place. These are made of larger outside diameters than the old shafts. The middle part of the axial holes is expanded on a large mandrel and the ends are closed down at the bearings. These shafts are of the same weight as those originally in use, but are much stiffer, as the metal is so disposed as to give the greatest amount of strength for a given weight.

The sketch and table on the next page give a comparison of the strengths of the above-mentioned three types of stern-wheel shaft. Taking the first shaft as solid, made of wrought iron, 14 inches in diameter and 30 feet long, and representing its strength by unity, the strength of the other shafts is given in terms of this value. The second shaft has the same diameter, is bored with a 3½-inch hole, and is 7 per cent. lighter

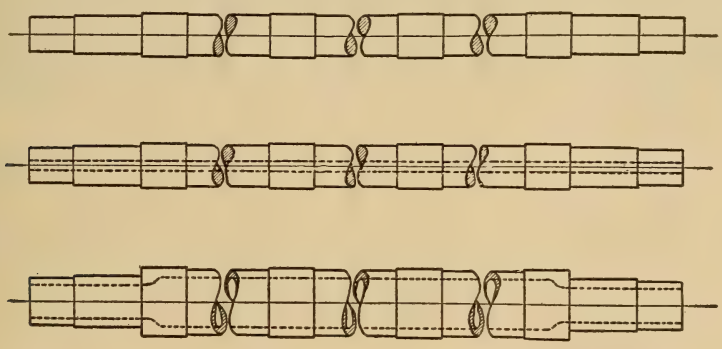
than the solid shaft. The third shaft is "hollow forged" on a mandrel, with the ends closed down. The outside diameter is 22 inches and the inside diameter 17 inches. It has the same weight as the solid shaft.

		Relative Strength
1st Shaft,	Solid Wrought Iron	1
2d "	Bored Medium Carbon Steel, oil-tempered	2
"	Bored Nickel-Steel, oil-tempered	3
3d "	Hollow Forged Nickel-Steel	4
"	Carbon Steel, oil-tempered	5
"	Nickel-Steel	6
"	Nickel-Steel, oil-tempered	7

When, in 1893, the machinery for the great electric power plant at Niagara Falls was being considered, the turbines, which had already been contracted for, were of peculiar design, in which the column of falling water was high enough to supply sufficient pressure to balance the weight not only of the revolving turbine itself, but also of the vertical shaft and the electric dynamo on its top. These turbines required, for efficient regulation, a fly-wheel effect, which, it was expected, would be supplied in the design of the dynamo to be selected. All of these latter designs, when submitted, consisted in an armature revolving inside of a stationary field ring. When the necessary fly-wheel was added, it was found that the accumulated weight was too great for the balancing water pressure, and it was thought that the accepted turbines would have to be discarded.

When this situation was brought to the attention of Prof. George Forbes, who was one of the staff of electrical engineers upon whom devolved the duty of solving the problem in hand, it at once suggested to his mind that a dynamo could be designed in which the field magnets would revolve outside of the armature and that the ring supporting the magnets could be made of such a weight as to constitute itself a fly-wheel. It would be necessary in such a design, however, to substitute for wrought iron, which, owing to its high magnetic permeability had always been used for this part of the generator, some metal of higher physical properties, in order to resist the centrifugal stress due to the high speed of rotation.

Fortunately, at this time the magnetic properties of nickel-steel were being investigated, and the fact that its magnetic permeability was as high as that of wrought iron became known. The physical properties of this metal were amply high to meet the severe requirements of the case, and it seemed as if the practical solution of the difficulty devolved upon the ability of the manufacturers to produce forged rings of nickel-steel 11 feet 7⅜ inches in diameter, 4 11-16 inches thick, and 4 feet 2¾ inches wide. Fortunately, the 1400-ton hydraulic press had just been completed at the works of the Bethlehem Iron Company for the purpose of forging armour-plate, and the distance between the vertical supports of the cylinder being over 12 feet, there was ample space provided for the forging of



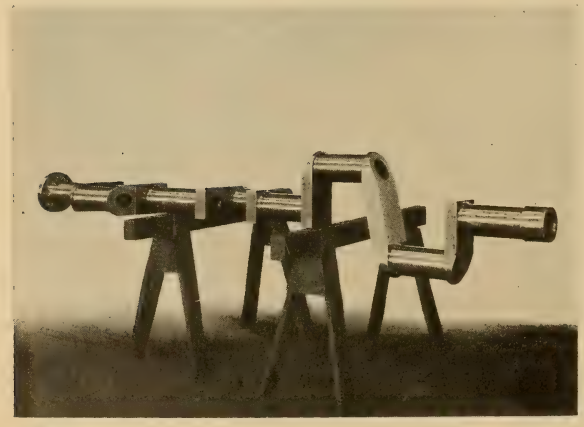
THREE TYPES OF STERN-WHEEL SHAFT, ONE SOLID; ONE WITH A HOLE BORED THROUGH IT; AND ONE HOLLOW-FORGED

these rings. Dr. Coleman Sellers, consulting engineer for the Niagara Construction Company, stated at a meeting of the American Society of Mechanical Engineers, held at Niagara Falls in 1889, that had it not been for the existence of this hydraulic press, the completion of this great electric power plant on its present lines could not have been carried out.

The peripheral speed per minute of these rings when running normally, at 250 revolutions, is 9300 feet, or more than a mile and three-quarters. As the magnetic attraction between the poles of the field magnets and the stationary armature acts against centrifugal force, the fibre stress in the metal is lessened, and, in fact, is only 5052 pounds per square inch under normal conditions. Should abnormal conditions arise and the ring rotate at double the above speed, the fibre stress would be increased to 13,000 pounds per square inch. As, however, the elastic limit of the metal of these rings is 50,000 pounds per square inch, shown in test bars taken from the forgings themselves, and as the mechanism is so adjusted that by no possibility can it reach this latter speed, there can be no danger of accident from the bursting of a ring.

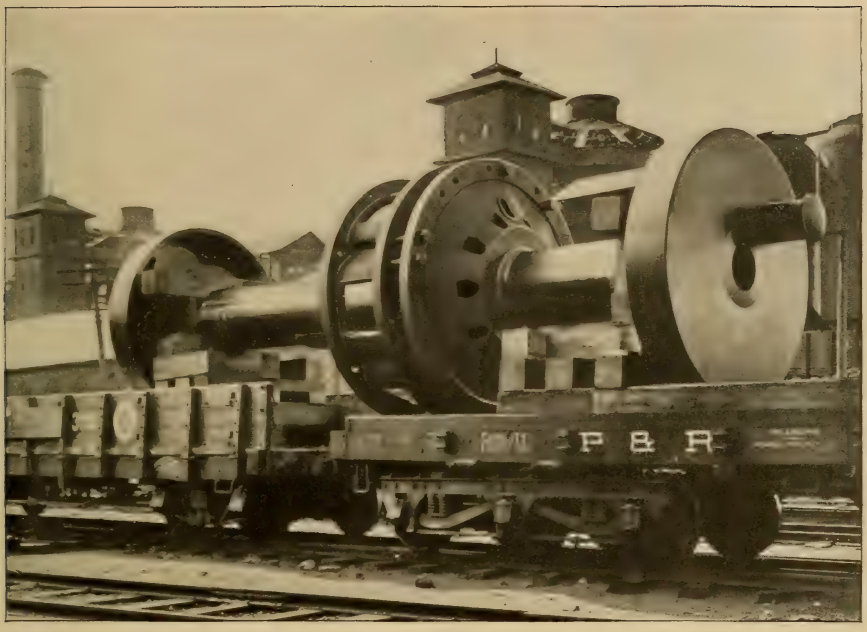
Since the completion of this first great central plant for generating power for distribution others, employing steam instead of water as the dynamic force, have been erected, and the size of the power generating units has more than doubled. In the development of the electric street railway industry many examples might be mentioned. One, however, will indicate the sizes of forgings which have already been called for. The Boston Elevated Railway has engines of 8000 H. P. with nickel-steel shafts 39 inches outside diameter, with a 17-inch hole through their axis, weighing 63,000 pounds. These engines make but seventy-five revolutions a minute. Mr. Charles T. Porter has recently shown the writer the design of a high-speed engine of the same horse-power capacity, but which is intended to run at 300 revolutions, the oil-tempered, nickel-steel shaft of which would be but 12 inches in diameter, and it would be provided with a 4-inch hole through its centre.

The great engine plant of the Calumet & Hecla Copper Mine, in Michigan, which has the reputation of being the finest of its kind in the world, has its pumping engines supplied with forgings of nickel-steel, and many of the engines purchased in recent years for the Anaconda Copper Mines, in Montana, have the same material specified for their forgings. Following these examples, engineers of waterworks, city engineers and others have been led to investigate the merits of nickel-steel, and many of the large municipal pumping plants of the principal American cities have been furnished with pumps of which the specifications called for forgings of nickel-steel, oil-tempered and annealed.



A FOUR-THROW OIL-TEMPERED NICKEL-STEEL CRANK SHAFT FOR A HIGH SPEED YACHT ENGINE OF 4000 H. P. DIAMETER OF SHAFT AND PINS, 5 INCHES; DIAMETER OF BORE, 3′ 3½″ X 4′; LENGTH, 9′ 5″; WEIGHT, 579 LBS.

Throughout the country, as old engines are having their capacity taxed, their old shafts are showing signs of weakness, and others of nickel-steel are replacing them. As old engines outlive their usefulness and new ones of greater power are substituted, the latter are



OIL-TEMPERED NICKEL-STEEL CRANK SHAFT FOR AN 8000 H. P ENGINE FOR THE BOSTON ELEVATED RAILWAY. DIAMETER IN CENTRE, 39 INCHES; DIAMETER OF AXIAL HOLE, 17 INCHES; LENGTH, 27 FEET 10 INCHES; WEIGHT, 63,000 LBS.

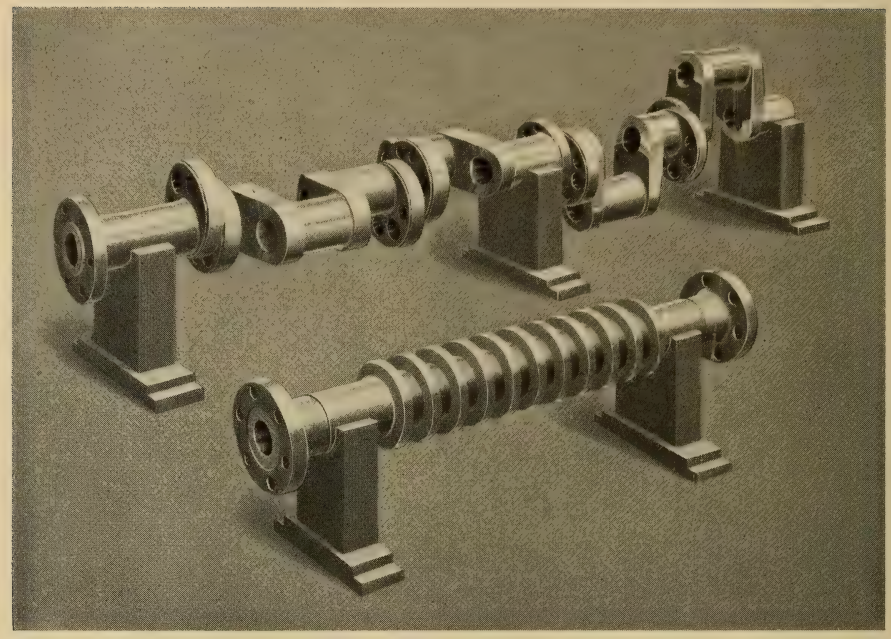
equipped with nickel-steel forgings, for engines of the same size, if built of stronger material, can be run at higher speed and thus transmit the increased power. The following instance of this practice will illustrate the principle referred to. In 1896 Captain Charles H. Manning, superintendent of the Amoskeag Manufacturing Company, operating the largest cotton mill in the world at Manchester, N. H., finding that the draughts upon the water supply of the Merrimac River by new mills erected along its banks were, in seasons of drought, causing serious inconvenience to his mill, determined to put into his power plant an auxiliary engine of 2000 horse-power, to use when necessary. It was found that this engine would have to be inserted in the line of main shafting and be coupled directly to it, as there was no other place to set it. The speed of the shafting, however, being 230 revolutions per minute, required an engine of special design in order to be amply secured against accident from the breaking of the reciprocating parts, owing to the high speed of rotation.

An engine was finally built and furnished and has for the past six years given remarkable satisfaction, in points both of operation and economy of fuel consumption. The specifications for the forgings for this engine read as follows:—

"The connecting-rods, crosshead and crank-pins and crankshaft are to be open-hearth nickel-steel, all hollow, and of the following physical properties:—

"Elastic limit, 50,000 pounds; elongation, 25 per cent. These qualities are to be obtained in the United States Navy standard test bar, ½ inch in diameter by 2 inches long between gauge marks."

When the bicycle fad was at its height the Columbia Bicycle Company made a special grade of wheel, which was not only exceptionally strong, but also exceedingly light. In these wheels the frames, as well as handle-bars and seat-posts and rods, were all made of nickel-



CRANK AND THRUST SHAFTS FOR THE U. S. TORPEDO BOAT "SHUBRICK," MADE OF OIL-TEMPERED NICKEL-STEEL; 6¾ INCHES OUTSIDE DIAMETER; 4 INCHES AXIAL HOLE, EACH FORGED IN ONE PIECE; CRANK SHAFT TURNED ON 13 CENTRES. WEIGHT OF CRANK SHAFT, 1650 LBS.; WEIGHT OF THRUST SHAFT, 1800 LBS.

steel which contained 5 per cent. of nickel, and, when oil-hardened and annealed, developed an ultimate tensile strength of 240,000 pounds per square inch. By the use of this high-grade material it was claimed by the makers that a bicycle was provided with strength enough to resist the maximum shock likely to be incurred in ordinary riding, and that the structural parts of the machine had the same life as that of the bearings and working parts. When the bicycle went out of fashion the automobile took its place, and now some of the makers of the highest grades of these machines are working along the same lines, supplying them with axles and other parts made of nickel-steel, oil-tempered and annealed.

At a meeting of the Railway Master Mechanics' Association in 1889, previously mentioned, a committee which had devoted a year to the subject reported the results of its investigations into nickel-steel. Although the report amounted to little more than a bibliography of the subject, the discussion at the meeting brought it prominently before the railway engineering fraternity, and, to the surprise of all, developed the fact that the nickel-steel forgings used by many railways had not given the satisfactory service that had been expected of them. It was brought out plainly, however, that these roads had either bought the raw material in the shape of nickel-steel billets and had them forged into shape by their own blacksmiths, or had bought the forgings from small forges, which, in turn, had purchased the nickel-steel billets in the market, and had attempted to forge them in the same way as they had daily been accustomed to make their wrought-iron forgings.

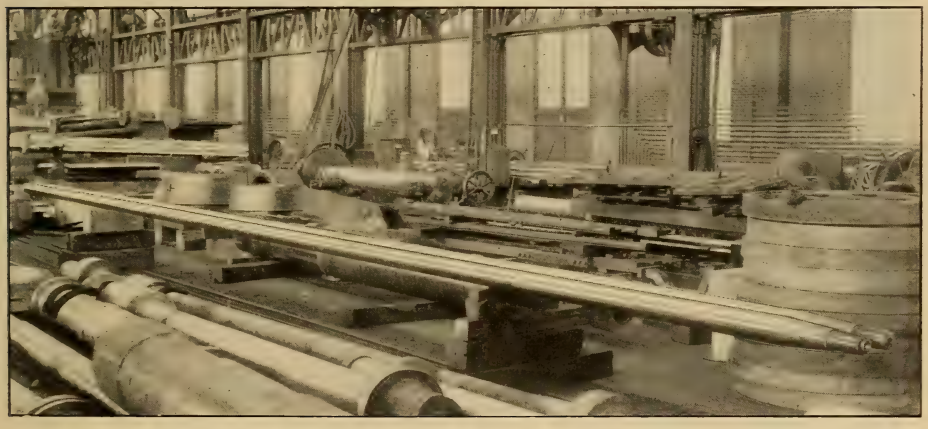
But nickel-steel was known by those who were familiar with its manipulation as a metal extremely sensitive to sudden, even though slight, changes of temperature. Care must be taken to avoid chilling the metal through careless handling when hot. Contact with

wet or cold ground, exposure to rain or draughts of air, to which wrought iron would be totally insensible, might cause a surface chilling which would seriously affect the properties of the metal. It was, therefore, made perfectly clear that men who knew little or nothing about the new high-grade material could not be expected to handle it intelligently, especially as they were not equipped to forge it at correct temperatures, nor to anneal or oil-temper it properly even if they knew the meaning of those phrases, and that the forgings so turned out could by no means possess the high physical properties that they should have possessed if they had been properly made.

Since then there has been a better understanding of the situation among railway men. They now order their nickel-steel forgings by specifying physical properties so high that they can be met only by this material when properly manufactured, and thus their production is limited to those forges which are equipped with the necessary apparatus to handle this metal. As a consequence, nickel-steel forgings for railway service are now being made properly and are giving proportionately better service.

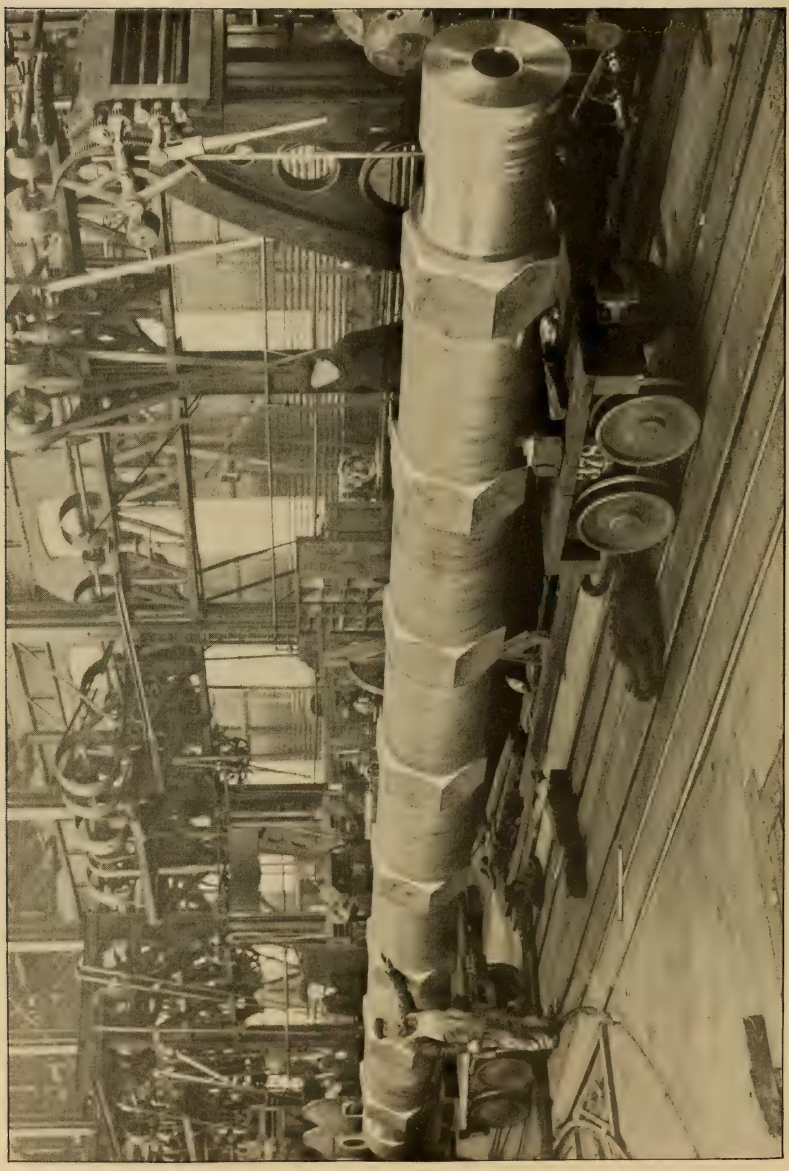
It has been said that nickel-steel heats in such service as that required of locomotive axles. All axles heat if not sufficiently lubricated, and nickel-steel axles will not be excepted; but it has not been shown that the coefficient of friction of this metal is different from that of other steel, or that, all conditions being the same, there is any special reason for its heating.

The experimental locomotive in the testing laboratory of the Purdue University, at Lafayette, Ind., is equipped with nickel-steel forgings throughout. They are all hollow, oil tempered and annealed. In the years that this engine has run, and during this time it has covered over 16,000 miles, attention has never been directed to the undue heating of any of the bearings, they having received only the ordinary care which had been given to the lubrication of the bearings of other similar engines equipped with ordinary steel axles. Tests are now being conducted at this laboratory which are expected to permanently dispose of the above-mentioned illusion.



OIL-TEMPERED NICKEL-STEEL TAIL SHAFTS FOR THE U. S. TORPEDO BOAT "SHUBRICK;" SIX INCHES OUTSIDE DIAMETER; 3¼-INCH AXIAL HOLE; 28 FEET 4¾ INCHES LONG; WEIGHT, 2610 LBS. EACH

The satisfaction attending the service of locomotive axles, tires, connecting and piston rods, crank and crosshead pins made of this metal led the Pennsylvania Railroad in 1899 to test its efficiency in rails on one of the curves of the famous "Horse Shoe Curve," near Altoona, Pa., where the service is exceptionally severe and the life of ordinary steel rails was so short that



A HOLLOW-FORGED NICKEL-STEEL SHAFT FOR A STERN WHEEL STEAMER. LENGTH, 47 FEET; OUTSIDE DIAMETER, 31 INCHES; INSIDE DIAMETER, 21 INCHES; CLOSED DOWN TO 10 INCHES AT THE ENDS. SHIPPED WEIGHT, 80,220 LBS.

frequent renewals of the track became necessary. These rails were made by the Carnegie Steel Company of steel containing 0.50 per cent carbon and 3¼ per cent. nickel. James T. Richards, Engineer of Maintenance of Way, in a personal communication to the writer, states that "so far as the railroad is concerned, the rails are very hard and wear well. They will certainly wear three or four times as long as the ordinary soft steel rail. The hardness of the rails makes them brittle, and for general use, if nickel-steel rail is to be made, it should have greater toughness than this lot." This is a good record for an experimental lot. In all probability the next attempt will be much more satisfactory.

There has, so far, been little demand for structural material or plate made of nickel-steel. It is but little less corrosive than the ordinary steel, so that not much benefit can be obtained along these lines by its substitution, and there have been so far but few instances where the reasons for lightness were so imperative as to warrant any increased expenditure to obtain it.

Bars of T and Z section and hull plate, as well as boiler plate, have, however, found place in the navies of the foremost nations, and, to a slight extent, in the merchant marine and in land practice. But the fact that the elastic limit of this metal is about double that of ordinary steel and equal to the tensile strength of the latter will undoubtedly bring it to the front in this service in the early future. The proposed North River bridge at New York, with its enormous spans, demanding a saving of weight wherever possible, will afford excellent opportunity for some mill to equip itself for rolling and treating this material. Boiler plate and tubes may be made thinner by the use of this steel, and thus the flame can approach closer to the water and make more efficient use of the evaporative power of the coal.

Experiments made by Maunsel White, engineer of tests of the Bethlehem Steel Company, show that a ¾-inch rivet of nickel-steel can replace a 1⅛-inch common steel rivet and thus save considerable plate section and give increased strength.

Nickel-steel of 4½ to 5 per cent. nickel, oil-tempered and annealed, has been used largely for rifle and gun barrels. This steel has an elastic limit of 80,000 pounds per square inch and an elongation of 20 per cent. in test bars ½ inch in diameter and 2 inches long. Similar material, but differently treated, and used for hydraulic cylinders, has shown a tensile strength of 150,000 pounds per square inch and an elastic limit of 125,000 pounds per square inch.

Little has been said of the use of nickel-steels containing high percentages of nickel. They are, in the first place, expensive, and, as has been shown, have certain properties which make them available only for special purposes. At the present cost of nickel,—forty-five to fifty cents per pound,—each percentage of this element in the ferro-nickel alloy adds about half a cent per pound to its cost. The usual addition of 3 to 3½ per cent. of nickel increases the cost of the raw material by about a cent and a half per pound. For certain purposes nickel-steel containing from 10 to 50 per cent. of nickel are serviceable almost regardless of cost.

C. E. Guilleaume, in "Comptes Rendues," 1898, records 15 per cent. to 25 per cent. nickel-steels which expanded instead of contracted during cooling. For certain laboratory apparatus metal having this property becomes invaluable. Twenty-five to thirty per cent. nickel-steels have coefficients of expansion varying regularly from 0.000014 to 0.000001. These also have their uses. For instance, an alloy of the same expansion as glass (0.0000086) may thus be prepared and used for lens mounts, telescopic or microscopic, and by the substitution of a 35 per cent. nickel-steel pendulum for one of brass the daily variation due to expansion can be reduced in the proportion of 12 to 1.

Guilleaume also speaks of certain of these steels which lose their magnetism on heating and recover it on cooling. Use for these metals is found in circuit

breakers, automatic fire alarms, etc., in which an electric current is broken by a rise in temperature produced either by the heating effect of the current or by an exteral source of heat.

Resistance wire made of 25 per cent. to 30 per cent. nickel-steel has forty-eight times the electrical resistance offered by copper to the passage of the electric current, while German silver has but eight times the resistance. These wires are nearly incorrodible, and, having a high tensile strength, are less liable to break than German silver. After repeated heating and cooling German silver becomes brittle, while nickel-steel retains its original elasticity.

Many other uses are being found for the various grades of this metal, and, as time goes on, undoubtedly the whole range will find its place in the trades. The possibilities of nickel-steel, even as we now know it, are sufficient to meet every demand in the field of industrial progress, even though we scan that field as far as finite prevision can descry an horizon.

PRODUCER GAS

ITS USE IN ENGINEERING AND SHIPBUILDING

By F. J. Rowan

The following remarks are extracts from a paper recently read before the Institution of Engineers and Shipbuilders in Scotland. The original paper was accompanied by a large number of diagrams, showing producer gas applications to many different kinds of furnaces, and some descriptive data of these also were given.—THE EDITOR.

PRODUCER gas is the generic name for the product of what may be called the comparatively slow resolution of solid fuel by means of heat in apparatus of a variety of designs. While in the ordinary system of gas-making practised in gas works the heat applied to the exterior of the retorts for the distillation of the coal contained in them, is obtained from coke or other fuel distinct from the charge of coal which is being distilled (although the coke may be the product of coal previously distilled), in the producer system the heat is obtained in the interior of the producer by the combustion there of the solid portion of the charge of fuel which is being gasified.

It has become so much the fashion to affix the name of the inventor or designer of the form of producer used to the product of that apparatus, and thus to speak of "Siemens gas," "Dowson gas," "Mond gas," and so on, that ordinary people may be excused for not recognising the fact that the "gas" is virtually the same in all these instances, as the process followed is to all intents identical in all kinds of apparatus employing internal combustion for the production of combustible gas. There are such differences in detail as the employment of coke or anthracite in some cases, of bituminous coal in others, of the use of a smaller or larger amount of steam along with the air required for combustion in the producer (resulting in a greater or less percentage of hydrogen in the gas, and in the preservation of the ammonia formed from the nitrogen of the coal), as well as differences in the form, size, and arrangement of different producers; but none of these affect the principle upon which the production of gas is based, or the main features of the process as a whole. It will thus be seen that an erroneous idea is conveyed by the adoption of distinguishing names, and that, instead of there being so many inventors or "discoverers" of new kinds of gas there are only inventors of different forms of ap-

paratus, the object of all of which is the preparation of practically the same kind of gas. As to which form of apparatus is the best, there are, of course, different opinions, but practice and experience have demonstrated some well-defined conditions to which a "producer" must conform in order to be a really good one.

In order to understand the *raison d'être* of the gas producer or the fundamental principle underlying the advantages of employing this method of treating fuel, we have to consider the formation and use of flame, and the various chemical reactions which together constitute what is called combustion. The production of flame may or may not accompany combustion, for the chemist knows several actions which can be truly termed combustion in which no flame is formed. The use of electricity, moreover, furnishes us with an illustration of "incandescence" or glowing, in which there is neither flame nor combustion.

In all industrial heating operations, however, except a very few, the existence of flame is imperative, and, without entering minutely into the physics of the subject, we may accept the definition that ordinary flame is gas or vapour of which the surface is burning, with the emission of light. The "burning" is the result of combustion between the gas and an atmosphere, which is usually atmospheric air, in contact with the surface aforesaid. The problem in all these heating operations is how to obtain a continuous supply of flame of the requisite quality and of the desired temperature, and this, therefore, leads to the obvious conclusion that for effective heating we must obtain a supply of combustible gas. It is really what is attempted, even with direct coal-firing, although many people do not realise that there is any intermediate condition between that of the solid coal which enters and that of the flame which issues from a fire, any more than they do so in the case of a candle or of an oil lamp. It is a fact, nevertheless, that the first step in the utilisation of coal for heating, as in that of a candle or of oil for lighting, is the transformation of the solid or liquid into the gaseous form. In an open domestic fire we can see the gradual resolution of the solid fuel into the gaseous form, and can obtain some evidence of the fact that the burning of coal is a heat-absorbing as well as a heat-yielding operation. It does not matter whether the coal is burned on a grate or in a producer, the fact remains that heat is absorbed in the decomposition of the complex hydrocarbons which constitute the mineral and in the change of physical state from the solid to the gaseous. In the domestic fire the gases thus formed are burned directly on the surface of the fire, but in the producer (which is practically a fire with the upper part enclosed and screened from access of the air required for the combustion of these gases) the gases are led off to yield their sensible and latent heat elsewhere.

There is one feature of the heating effect of an open fire which is absent from heating by means of the gas producer, and that is the mass of glowing coke which usually constitutes the under layer of the fire. By some people great stress is laid on the radiating effect of this incandescent mass, but that effect is much over-estimated, because it can be only intermittent, on account of the operation of adding fresh charges of fuel, and it is only in such furnaces as those of boilers that the radiating effect can be utilised for heating anything beyond the fuel, as in other furnaces the fuel occupies a distinct compartment. The radiant effects produced in the body of these other furnaces are due to the flame, and these are much more complete and far-reaching than any that are due to the incandescent coke.

In considering the use of producer gas, it is sometimes urged against it that some of the heat of the fuel must be lost in the process of gasification, and that there will, therefore, be no economy in employing it. This objection is founded upon an incomplete view of the facts of combustion, as is also the practice of estimating the heat value of a solid fuel by assuming all its carbon to be capable of yielding the full theoretic thermal value of pure carbon burned to carbon dioxide. That is a false assumption,

because, in burning solid fuel, part of the heat of combustion is absorbed in transforming the solid into gaseous matter, part in evaporating the moisture originally held in the fuel, and part in dilating and heating the waste gases, so that the theoretical heat of combustion is not the available heat. In burning producer gas we are wholly freed from two of these sources of loss and have a much less amount of the third.

Taking the following as a fair specimen of Lanarkshire splint coal, the analysis of which is given by Sir I. Lowthian Bell, the heat values are as shown:—

	Per Cent.
Water given off at 212° H	11.62
Carbon (fixed 53.41, volatile 12.59)	66.00
Hydrogen (available H = 2.96)	4.34
Oxygen	11.09
Nitrogen	0.94
Sulphur	0.59
Ash	5.42
	100.00

If burned in an open grate, the theoretical heat yield would be:—

		Calories G. C. Units
Carbon (fixed)	53.41 × 8,000 =	427,280
Hydrocarbons (C. volatile 12.59, available H. 2.96)	15.55 × 12,000 =	186,600
Total		613,880

To arrive at the available heat we must deduct the heat required for

	Calories
Evaporation of water in coal	11.62 × 622 = 7,227
Expelling gaseous matters in coal	= 57,920
Total	65,147

Then 613,880—65,14754 = 8,733 Calories.

If this coal were turned into producer gas, with only air blast, and the gas were burned cold, then the heat value would be:—

		Calories
Carbon	53.41 = CO 124.62 × 2400 =	299 088
Hydrocarb's (same as above)	15.55 × 12,000 =	186,600
Hydrogen derived from moisture in blast	0.288 × 28,600 =	8,236
Total heating value		493,924

The difference between these two numbers, viz., 548,733 and 493,924 = 54,809, represents only 9.98 per cent. of the heating value of the coal. Most of this difference would, however, disappear if a steam jet blast were used and the sensible heat of the producer gas were taken into account. It is to be remarked, too, that the figure given above for the volatilisation of the solid matter of the coal is probably too low, as it does not allow for the gasification of the fixed carbon, but only for the hydrocarbons existing in the coal. The heat lost in waste gases is excluded in both cases.

Some years ago it was shown by Mr. D. Clerk (in the discussion of a paper on "Gas Producers," read by the writer before the Institution of Civil Engineers) that with pure carbon in a producer and air alone, without steam, a perfect producer would give a mixture of CO and N, in the proportions of one volume of CO and two volumes of nitrogen. The gases would leave at a high temperature, and, if cooled before use, would yield, in burning, only 70 per cent. of the theoretical value of the original carbon. This apparent loss in gasifying, therefore, should be avoided in either of two ways:—"(1) By retaining the heat in the gas formed; (2) by abstracting heat from the gas formed in such a manner that it might be rendered available in a chemical reaction to give more inflammable gas." This latter can be accomplished by the use of steam. "Mixing steam and, in the proper proportions, air supposed to have given to it by regeneration all the heat of the issuing gases, and supposing no loss by conduction, then pure carbon would yield a gas of the following composition:—

CO	= 38.7
H	= 16.4
N	= 44.9
	100.0

"This gas (Mr. Clerk stated) would, on burning, give the same amount of heat as the direct burning of the original carbon; it was the best gas capable of production from air, steam, and carbon, and might be used as a standard of efficiency for producers."

It has been since then pointed out that the higher the proportion of fixed carbon to volatile matters in coal, the greater will be the loss in gasification, so that whilst anthracite is the most expensive fuel to use, if carbonaceous shales (which are at the opposite point as regards composition) are mixed with ordinary coal in a producer, the gas-making process may become theoreti-

cally perfect as far as the heat equation is concerned.

The quantity of steam used in the ordinary steam-jet blast (where ammonia is not recovered from the coal) is very small. In a good blower, one pound of steam suffices to force into the producer twenty pounds of air, and as less air is wanted in the producer than the quantity usually required for complete combustion of the carbon to CO_2, it is probable that about one-half pound of steam per pound of coal is the average quantity required in working producers.

GAS PRODUCERS

Turning now to gas producers, since their introduction by Bischof in 1839, and Ebelman in 1840, they have been used in a variety of forms. A good producer nowadays must be capable of being cleaned without in any way interfering with the continuous production of gas and without permitting the refuse to carry any heat or combustible matter to waste outside the producer. Hence the days of the open grate producer and of the closed hearth are numbered, as such types are obsolete and are rapidly being, or have been, abandoned for producers with water bottoms. These may be divided into two classes, the distinguishing feature being a most important one, and even vital to efficient and economical working. These classes comprise:—(1) those producers which send the blast into the fuel in a lateral or radial direction, and (2) those which do so vertically. Of course, the air, or air and steam, must ultimately in all producers ascend, in order to reach the gas outlet; but the primary direction given to it on entering the producer is the important point to which the writer desires to direct attention.

1. When the blast enters the producer at either the centre or the sides, and is distributed laterally before it can ascend, the centre of the mass of the fuel is not in the direct path of the air, and the most vigorous combustion does not take place there, but is carried towards the walls. The effect of this is to make the walls too hot, favouring loss of heat by radiation, overheating and softening the brick lining, with consequent formation of refractory clinkers, and often (more especially where the blast enters the producer by tuyeres or passages in the side walls) allowing uncombined air to escape upwards along the walls and ignite the combustible gases in the upper portion of the producer. This latter effect may be detected by the percentage of carbonic acid in the producer gases. The percentage of unburnt cinder, coke, or coal in the refuse is another proof of imperfect combustion in such producers.

2. Of the second class referred to above, the only example with which the writer is acquainted is the Duff producer. No other producer has been as yet introduced which combines with a water bottom the means of delivering the air vertically in the very centre of the mass of the fuel, and yet of distributing it evenly throughout the whole mass. This power it owes to its ingenious "grate" or sloping grid, shown on page 504, which is placed right across the centre of the producer at the bottom, presenting no obstruction to the passage of the air directly upwards through the centre of the fuel, and, on account of the angle of the grate, distributing the air over the main surface of the section of the producer. As showing the wide difference between the proportions of the different producers, Mr. Duff stated, in the discussion of a paper by Mr. Wilson before the West of Scotland Iron and Steel Institute, that the blowing area in the Duff producer grate was 1720 square inches, as against 160 square inches in the tuyere of the Wilson producer of a similar capacity. Such proportions could not fail to exert a marked influence on the completeness of the combustion of the fuel, especially when combined with the excellence of the Duff system of air distribution, and it may be confidently asserted that no one has seen the perfectly burned ash, with a minimum of hard clinker, which issues from the Duff producer, equalled in the working of any other. The quality of the refuse is an unfailing test of efficient working, and one to which attention cannot be too strongly directed.

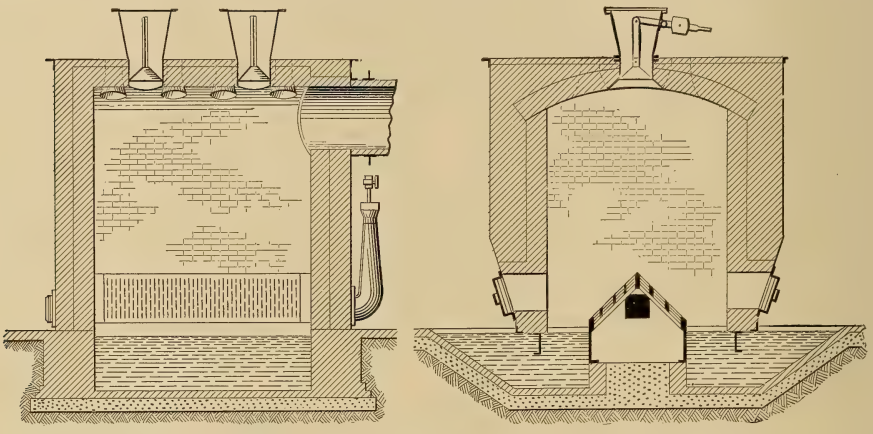
As to what is the proper basis for the estimation of the efficiency of gas producers, opinions differ. Mr. C. F. Jenkin defined the efficiency as the ratio of the heat contained in the gas as it leaves the producer to that contained in the coal from which the gas was made; but, in order to obtain this ratio, continuous analyses of the gas and observations of its temperature are required, and these are seldom available. Moreover, "the heat contained in the coal" seems to be not so fair a basis of comparison as "the available heat" obtained from the coal.

Mr. H. A. Humphrey, in a discussion of his paper on "Power Gas and Large Gas Engines," before the Institution of Mechanical Engineers, pointed out that the term "efficiency" might be used to express a variety of different ratios, or that the ratio between the original fuel and the producer gas might be estimated in either of several ways. None of these seems any clearer than the one proposed by Mr. Dugald Clerk, already referred to, which has the convenience of giving a standard with which analyses of producer gases may be readily compared.

Dealing with a table of about fifty analyses of the gases yielded by different producers, Mr. Clerk stated that none of them showed an efficiency of 80 per cent. on his basis, although some closely approached that figure, but that 80 per cent. was a high efficiency. Now, taking the following analysis of gas from Duff producers, we see that on Mr. Clerk's basis it shows an efficiency of almost 81 per cent:—

CO	H	CH_4, etc.	CO_2	N
26.8	13.4	4.4	4.0	5 .4

This is not a picked analysis, but is stated to be the average of daily analyses ranging over a period of several weeks. The quality of coal used in the producers is, however, not stated.



VERTICAL SECTIONS OF A DUFF PRODUCER, SHOWING THE SLOPING GRATE

FURNACES FOR GAS

In the presence of an abundance of cheap coal, people seldom stop to consider how wasteful a machine a coal-fired furnace is. They argue that it has a comparatively low first cost and a comparatively simple construction, and if penalties for smoke nuisance can be avoided, it will do very well. It is the fact, however, that about nineteen-twentieths of the theoretical heating power of the coal are wasted in such furnaces when applied to welding, reheating, or forging, and a much greater proportion, or about sixty-nine-seventieths, where higher heats, such as for steel-melting, are required. Besides going far to prevent this great loss of heat, gas-fired furnaces present another element of saving to the user of them, and that is found in the fact that a much cheaper grade or quality of coal may be used in a gas pro-

ducer for firing furnaces than could possibly be used in direct coal-firing.

In considering the furnaces which are specially useful in engineering and shipbuilding we find there are:—(1) Furnaces for steel and iron making; (2) furnaces for metal heating; (3) furnaces for subsidiary heating operations; (4) furnaces for steam-raising and evaporating; (5) brick kilns; (6) furnaces for heating retorts in gas-works and the like.

In the first section are comprised open-hearth and crucible steel-melting furnaces, furnaces for puddling iron, and those used for welding iron, such as for making rolled bars and plates, forgings, and tubes. It is in connection with the high temperatures required in these operations that producer gas has won its greatest triumphs, the reversing regenerator furnaces, without which they could not be economically obtained, being almost impracticable with solid fuel.

Reheating furnaces for steel and iron, plate and angle bar furnaces, furnaces for rivet and bolt making, and for weldless chain making, do not require so high a temperature, and consequently may have either modified reversing regenerators or continuous regeneration of the air, or both air and gas.

The testimony of Mr. S. W. Johnson, locomotive engineer of the Midland Railway, as to the advantages of heating plates, angles, tyres, etc., by gas, is that, apart from economy of fuel, the indirect advantages of using gas are very marked, as there is less chance of irregular heating or overheating, and the necessity for carrying coal to the furnaces is dispensed with.

Foundry stoves, annealing and case-hardening furnaces come under the third head, and in these cases also, although the margin of possible saving in fuel is not great, gas firing has advantages of speed, steadiness of heating, cleanliness, etc., which are a recommendation in themselves.

Gas has been applied to firing steam boilers of various designs, more, however, with a view to economising labour and wear of boilers, to smokelessness and cleanliness, which the system ensures, than to obtaining a saving of fuel. An increased evaporative duty (amounting to from 18 to 25 per cent. in some cases) from the heating surface in a given time has been found to result from gas firing, due to the uninterrupted application of the gas flame. This also preserves the boiler from the alternating strains due to expansion and contraction from the heating and cooling actions of coal firing, which are ruinous to the structure of the boiler. The gas for boiler firing is usually taken from the main flue supplying other furnaces, so that it is rarely possible to obtain accurate figures of coal consumption for steam raising; but separate tests have shown an evaporation of 9 pounds and 10.59 pounds of water from and at 212 degrees Fahr. per pound of coal in the producer, cold air being used for combustion.

It is strange that whilst firms rarely grudge the expense of adding mechanical stokers to boilers, the cost of fitting gas firing, which is no greater in many cases, should be considered an obstacle to its adoption.

Other applications of gas to evaporating processes have mainly interest from the chemical engineering point of view, but one of perhaps wider interest is that of the brewers' coppers at Messrs. Guinness' great brewery in Dublin.

One other application of producer gas to furnaces which may be considered as directly connected with engineering and shipbuilding is that of heating the retorts in gas works. Various arrangements have been in use for several years for utilising the coke in producers which either formed part of the retort setting or were erected just outside in front of the retort bench and under the floor level of the charging house. Under such circumstances the producers were necessarily small, but Mr. William Foulis has introduced with success the novel plan of having large producers erected outside the retort house, the coke being charged into them while still red hot.

POWER

No paper on producer gas would have any claim to completeness of view of the

subject if it did not in these days refer to the direct use of producer gas in gas engines. We are here, of course, on somewhat different ground from that on which the value of producer gas in furnace work has to be considered. It is not the direct production of flame that is in question, but the transformation of the potential energy of the fuel into the actual power of the engine. As compared with the steam engine the gas engine saves several steps in the transformation of energy, and this gives to the gas engine and gas producer a decided advantage. Some producers, such as those of Dowson in this country, and Lencauchez and Fichet in France, have been wrought for some years with anthracite or coke as fuel when the object was the production of gas for use in small gas engines. But since large-power gas engines have been successfully made, the field has become vastly wider and the employment of producers using bituminous coal slack, combined with appliances for the removal of tar and dust from the gases, and in some cases with plant for the recovery of ammonia as sulphate from the nitrogen of the coal, has become an accomplished fact.

According to the late Mr. Bryan Donkin, we may take the heat value of illuminating gas at 584 B. T. U. per cubic foot. That of producer gas made from coal varies, according to one authority, from 144 to 165 B. T. U., but, according to another, is properly 190 B. T. U. The gas from Mond and from Dowson producers is given as equal to 150 B. T. U. That is a favourable estimate of the gas made from Mond producers using slack coal, the ammonia being recovered from the gas (125 being about the usual figure), but is about the normal value of producer gas from coke or anthracite. The gas from blast furnaces using coal is equal to about 137 B. T. U. and from coke furnaces it averages about 100 to 110.

In comparison with average steam engines where producer gas is burned under the boilers to generate steam, 100 cubic feet of power gas, burned directly in a gas engine cylinder, will yield as much power as 400 feet burned under the boilers. The consumption of fuel in larger gas engines using power gas has now been brought under one pound per I. H. P. per hour.

As to the question of the distribution and cost of power gas, schemes are put forward for monopolising large tracts of country in the interests of one form of gas producer, as far as the right to distribute the gas to consumers is concerned. But that need not deter individual consumers within such districts from supplying themselves with producers for their own requirements, especially as by so doing they will obtain much cheaper gas.

The cost of production is barely above 1 penny per 1000 cubic feet with expensive coal. Thus, if we take coal at 10s. per ton in a producer gasifying 10 cwts. per hour, and working sixty hours per week, the quantity of gas yielded per ton being taken at 150,000 cubic feet, the labour cost as equal to 1s. per ton, and the charges for interest and depreciation at one-quarter the cost of the coal, we have per 1000 cubic feet:—

Coal	=	.80d
Labour	=	.c8d
Int. and dep	=	.20d
Total		1.08d

Of course, with the cheaper dross which would most commonly be used, the cost of the gas is less, and as the labour cost has been arrived at by taking 30s. per week as the wages of one man for one 10-cwt. producer, in the usual case in which several producers are at work together the labour charge will be proportionately less.

ANTHRACITE COAL MINING IN THE UNITED STATES

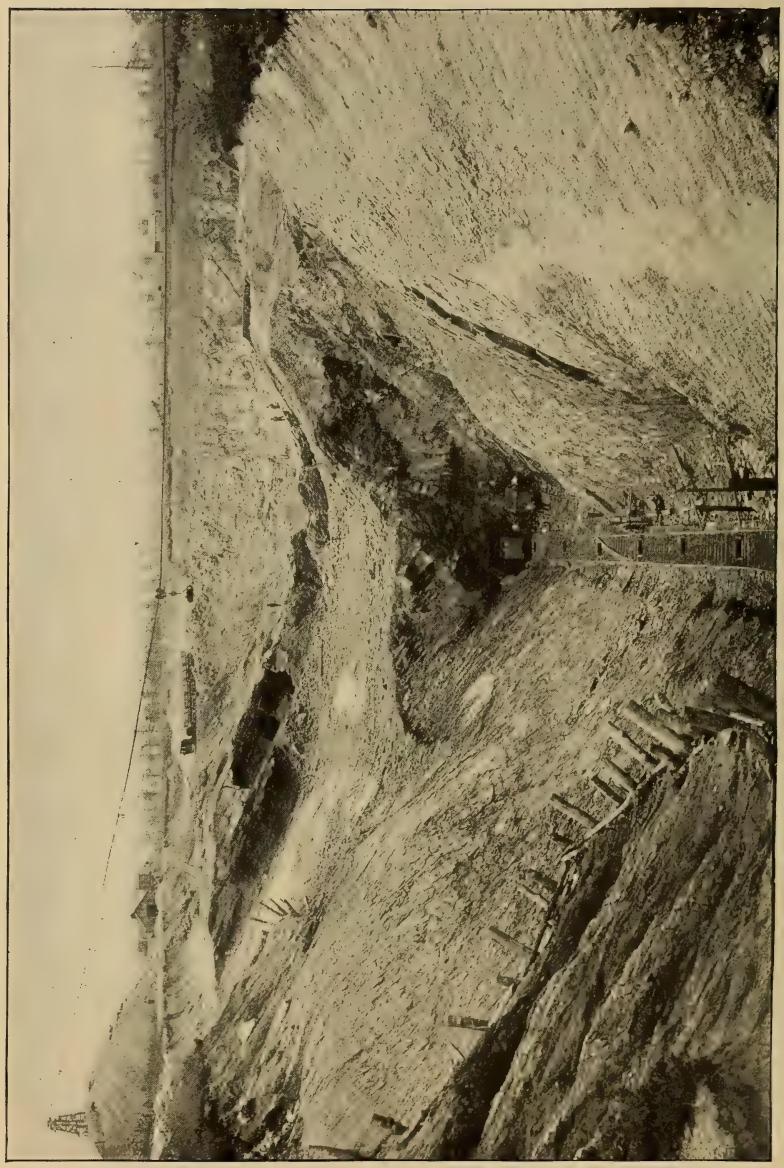
A SKETCH OF THE PENNSYLVANIA COAL FIELDS

By John Birkinbine, M. Am. Inst. M. E.

THE story of anthracite coal mining in the State of Pennsylvania covers a period of eighty years, for although the existence of anthracite coal was known before 1800, it was not until 1820 that any considerable quantity was mined. The initial shipment of 365 tons,—an average of one ton per day,—reported in 1820 has increased until upwards of 50,000,000 gross tons now represent the annual output, and the total quantity which has been shipped from the 470 square miles of territory embraced in what is recognised as the anthracite region of Pennsylvania has exceeded 1,175,000,000 tons. More than one-half of this total has been won from the mines in the past twelve years.

Contemplation of these enormous quantities suggests the marvellous assistance that this fuel has been to industrial development and personal comfort, not only in the State in which the material is mined, but also in other States, and in foreign portions of the world, because this fuel has been shipped liberally to different nations

MINERS AT MID-DAY LUNCH. A "COZY CORNER" ON THE 400-LEVEL



STRIPPING AT A COAL MINE AT CROSS CREEK, NEAR DRIFTON, PA.

and used to a large extent on steam vessels. The exportation of American anthracite coal in 1900 approximated 1,700,000 tons.

The earlier mining of anthracite coal stimulated the construction of canals, and these were followed by railways whose support has been largely derived from the tolls and tariffs on the coal forwarded. The anthracite coal region is a net-work of railways, and it is responsible for the construction of some important inclined planes to convey the coal over summits dividing one basin from another.

The transition of iron-smelting from the use of charcoal as a fuel to mineral coal was largely by the substitution of anthracite, and prominent advances in the development of blast-furnace practice are traceable to the application of anthracite coal as a fuel for smelting iron ores. It has made many industries possible and profitable, and has added enormously to the development and material wealth of the nation.

The anthracite coal fields of Pennsylvania are commercially recognised as divided into three geographic districts, the Schuylkill, the Lehigh, and the Wyoming, with a few outlying mines which are not directly associated with either of the three. These titles practically indicate that the mines are located in, or adjacent to, the drainage basins of the Schuylkill River, or the Lehigh River (both branches of the Delaware River), while the Wyoming region is in the basin of the Susquehanna River. Subdivisions of these districts are recognised in such local names as Mahanoy, Shamokin, Lykens Valley, Hazleton, Wilkesbarre, Pittston, Nanticoke, and others.

The mineral is found in the Blue or North Mountain range, the openings of the mines varying from 500 to 1200 feet above sea level, and the mining exploitations extend from the working of outcrops with moderate stripping to a depth of 1600 feet. Some of the veins lie nearly flat in one mine, but in others are at steep inclines approaching the vertical, the general features of the coal deposit being great basins with the seams or veins approaching the horizontal towards the bottom, while at the rims they are nearer vertical. Although the geology of the region has been carefully studied and excellent expert direction bestowed upon the workings, there is much yet to be learned and managers are constantly facing difficult problems.

There are folds, splits, and faults, and numerous complications which have added to the difficulties and expense of exploitation. Most of the coal is obtained from depths less than 1000 feet below the surface, and the system which has been used more generally than any other is room and pillar mining by

A FALL IN A GANGWAY

which not more than one-third, and often less, of the total coal in the veins has been obtainable. The anthracite coal fields, like most mining districts, were opened, and have been principally wrought, upon the veins which could be readily reached or cheaply mined, with the result that much coal has been sacrificed and subsequent operations have been more or less jeopardised.

The major portion of the exploitations has been in the upper veins, those lying in lower horizons having received comparatively little attention, and these form the bulk of the reserve. In a region where the veins are numerous, and of varying thickness, dip, and pitch,

A WORKING CHAMBER

with roofs at places secure and at others flaky, artificial support is essential, in addition to the liberal proportion of the vein left as pillars. Consequently, the demand for timber has depleted the nearby sources, and much of that used comes from other portions of the State.

The timber requirements vary greatly in different mines, some needing a small number of props of moderate size, and others numerous sets framed of as large timber as can be obtained. There is an instance on record in the Schuylkill district where the pressure of the superposed coal was sufficient to cause the bottom of drifts to swell, so that in a short time a gangway was practically closed. In this case the repeated creep of the floor, demanding its "taking up," resulted in mining coal representing a thickness of 40 feet.

The coal broken down in the underground workings is hoisted from the mines to breakers, some of which are of enormous capacity, treating thousands of tons of coal per day, and costing $100,000 or more to erect. In these the coal is broken, the slate is separated, and the various sizes are sorted and prepared for shipment. In the early mining the coal was sent to market as mined, without sizing, except to refuse the fine coal and that noticeably mixed with slate, and within fifteen or twenty years the demand for small sizes of coal was so limited as to encourage the waste of much of this upon the dump piles where slate or culm was stored.

It is estimated that up to that time from 20 to 25 per cent. of the coal mined was carried to these dumps. The wasteful methods of treatment are evident in many of the streams which drain the coal basins, for the beds of these consist largely of coal and slate washed

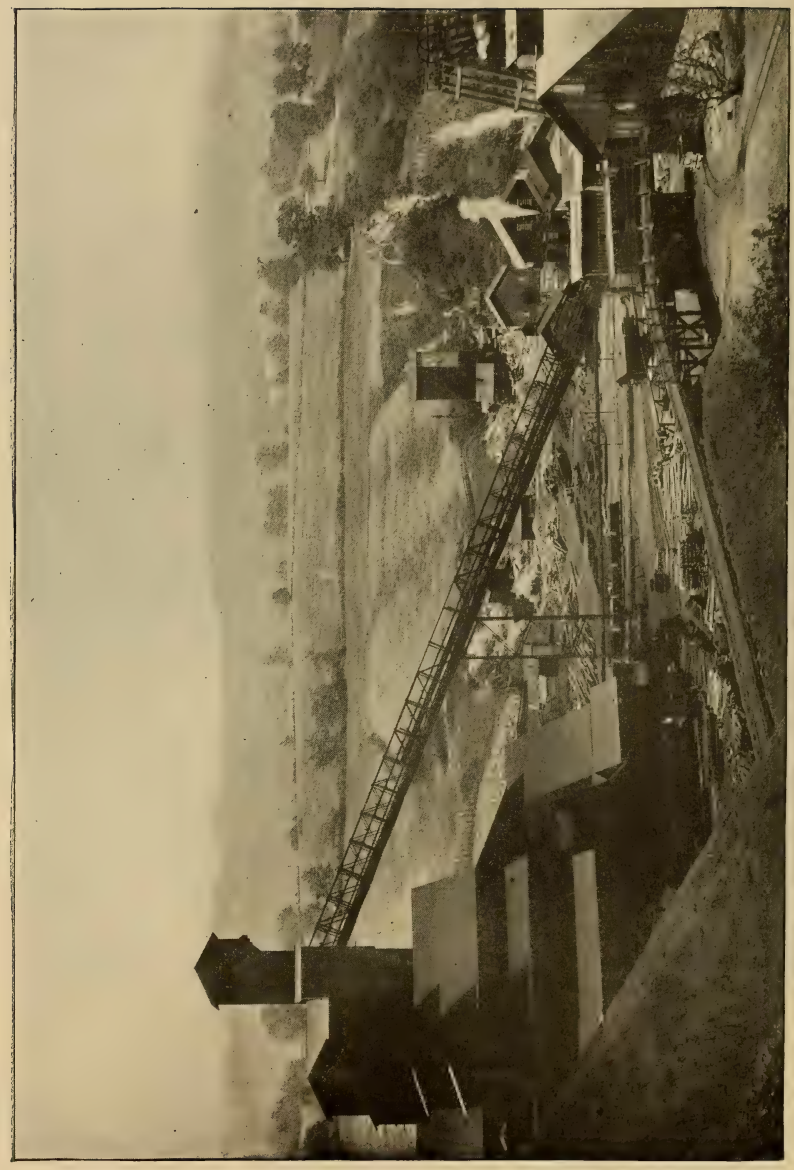
by storms from the waste dumps. For a distance of 30 or 40 miles below the workings farmers collect their fuel, and screeners make a good living by digging coal from the beds of creeks, or from bars formed on the banks during freshets, and selling it.

The waste in mining anthracite coal has received much attention from engineers, and a State commission some years ago investigated the matter and prepared an elaborate report. This report showed that the quantity of coal which it is possible to obtain from a mine depends upon the thickness of the vein and its pitch, the nature of the roof, the proportion of intercalated slate and bony coal, the methods of working adopted, the nature of the coal as affecting its fracture, the region, where the mammoth vein is about 60 feet in thickness. A cavity 100 yards square had been excavated under valuable buildings in the city of Shenandoah, and to prevent injury to this property the culm from adjacent piles was flushed into the cavity through a series of 8-inch bore-holes sunk from the surface to the excavated chambers. The result was sufficiently satisfactory to encourage the same effort at other mines where the waste has been crushed and carried in pipes down bore-holes, or through the shaft or slopes to the old workings. Where filling is a regular practice, the culm is taken directly from the breaker by a stream of water. Worked-out rooms or chambers are banked off with "stoppings" of slate and fine refuse. The pipes con-

FOUR HUNDRED FEET UNDERGROUND

uses to which it is to be put, and the sizes to which it is to be broken, as well as the method of breaking and sorting.

Within late years efforts to prevent settlement of areas partially worked out have been made by flushing the waste banks into the old workings. The initial attempt was made in 1887 at the Kohinoor Colliery, in the Schuylkill veying the washings from the waste dumps discharge near the highest point of the chamber, and the material, owing to its semi-liquid condition, assumes a flat slope, practically filling the space. The water draining off is lifted to the surface in the mine pumps. This refilling permits of no serious settlements, and prevents chipping of pillars, mak-



OLYPHANT BREAKER OF THE DELAWARE & HUDSON COMPANY AT WILKESBARRE, PA.

A COAL STORAGE PLANT OF THE LEHIGH VALLEY COAL CO., WEST SUPERIOR, WIS., INSTALLED BY THE LINK BELT ENGINEERING COMPANY, NICETOWN, PHILADELPHIA

A COAL BREAKER OF THE DELAWARE & HUDSON COMPANY, AT PLYMOUTH, PA., SHOWING BANKS OF CULM IN THE BACKGROUND

ing it possible to safely rob portions of a mine which could not be attacked under other conditions.

After the culm washed into a mine is well drained, it is so compacted and firm as to admit of drifts being driven through it. The method of refilling does away with expensive timber, cobbing or cribbing, and offers a suggestion for the protection of mines wrought in other mineral than coal. It also reduces the obstruction of valuable surface areas by piles of refuse. Mr. James B. Davis ascertained by experiment that a cubic foot of anthracite coal, finely comminuted, could be flushed in a space of 1½ cubic feet, and Mr. William Griffiths, M. E., found that to produce a compression of 10 per cent. would require about 0.9 of a ton weight per square inch of the culm. This would be equivalent to a column of sandstone 1800 feet high; that is, this weight would compress the culm in a 5-foot seam which had been completely flushed with it only about one-half foot.

He also found that the pillars of an anthracite mine begin to squeeze when the pressure is from 400 to 4000 pounds per square inch. He considers that culm, if properly flushed in the mine, becomes an ample safeguard against crushing, and, further, that this flushing is a decided protection against mine fires, no cases of spontaneous combustion having been discovered. He suggests a mixture of culm and water for the purpose of drowning mine fires, as this method would practically exclude the air and probably stop the fire. He further estimates that under average conditions a mine which is worked and flushed with culm for the purpose of remining it, will yield 20 per cent. more coal than would be possible without such flushing.

The transportation of fine coal by

means of water in confined pipes is not novel; in fact, years ago an effort was made to establish a line of pipes leading from the coal regions to New York and Philadelphia, through which finely ground coal, mixed with about an equal weight of water, was to be forced by pumps. The piles of culm about the anthracite coal mines have invited attention at different times, and among the suggestions for their utilisation was the production of gas from this coal, and its delivery by pipes to Philadelphia and New York, supplying en route towns convenient to the pipe line. These culm piles are often of immense proportions, and, besides being unsightly, they occupy ground which is valuable, or place excessive weight upon the territory which is undermined. Their immensity, and the knowledge that a considerable proportion of many of the piles is coal, have naturally attracted attention, and suggestions for crushing, jigging and briquetting the fine coal have been made from time to time. Fires have been burning in some of these waste piles for decades, and instances are not uncommon where an effort to reduce their size by burning has been made.

A number of these old culm heaps have been leased on royalty to parties who have erected washeries, running the entire bank through crushers and jigs, the coal being separated from the slate and sorted into "rice," "buckwheat," and "pea," and larger sizes, recovering, in some cases, over 50 per cent. of the entire cubical contents of the bank in the shape of marketable coal. Of the amount so recovered, in round numbers, approximately 25 per cent. is of pea size and larger, the remaining three-fourths being of the smaller varieties. The extent to which this has been done has been sufficient to cause the instigation of lawsuits, based upon the pollution and obstruction of streams by the waste of these washings, the current, in times of freshet, carrying this refuse for many

"RUN OF MINE"

PICKING PLATES

miles. As a rule, the waste banks of the older mines are more valuable for washeries, owing to the imperfect sorting which prevailed, and in consequence a larger amount of good coal was carried to the culm bank.

The possibility of producing fine sizes has, in time, resulted in the perfection of grates and stokers for economically using this coal, so that there is to day a ready market for large quantities of fine coal which displace the standard sizes coming from the breakers as lump, steamboat, broken, egg, stove, and nut coal.

The geological section of the anthracite coal measures show thirty veins or seams with a total thickness of 175 feet. At least nine veins of anthracite coal are recognised as workable in the region, six of which may be considered as persistent, these latter varying in thickness from 6 feet to 36 feet, and giving a probable average, for the total, of 75 feet of workable coal. The Mammoth vein in the Schuylkill district, however, has shown a thickness at individual points exceeding 100 feet, but the average of about seventy sections is 32 7 feet, while an average of thirty sections of the Buck Mountain vein is 13.6 feet. The Maple Hill Colliery, in the Mahanoy Valley, at a depth of 720 feet, cuts coal seams with an aggregate thickness of from 76 feet to 87½ feet.

As indicating the relative composition of various commercial sizes, the following is supplied by a leading Lehigh Valley producer:

ANALYSIS OF COMMERCIAL SIZES OF ANTHRACITE COAL

	Broken	Egg	Stove	Chestnut	Pea	Buckwheat	Rice	Birdseye
Fixed carbon	88 30	88.30	88.65	87.325	86.925	85.725	83.900	83.775
Volatile matter	5.75	5.75	5 15	5 650	6.315	6.160	6.585	6.500
Water	.80	.80	.95	825	.935	.840	.765	.700
Ash	5.15	5.15	5.25	6.200	5.825	7.275	8.750	9 025
Total per cent	100.00	100.00	100.00	100.00	100.00	100 00	100.00	100.00

Various estimates have from time to time been made of the quantity of workable coal in the anthracite coal basin of

Pennsylvania, the early exhaustion of which has been often prognosticated. These calculations have varied from 10,000,000,000 to 26,000 000,000 long tons. In 1892 Mr. J F. Jones, M. E., estimated the tonnage of marketable coal remaining in the anthracite coal field as 12,000,000,000 long tons, and calculated that one-quarter of this would be taken out in forty-four years, and that at the expiration of that time an annual output of 100,000,000 tons would be produced. At that time the output of the region was 40,500,000 tons per annum. Mr. Jones gave the then average cost on cars, for labour and material, as $1.34 per long ton, adding to this 22 cents to cover charges for improvement, discrepancies, taxes, insurance, and exhausted land, and 32 cents per ton to cover interest on the value of the coal lands and collieries, which he estimated as $300,000,000 for the year 1891.

This valuation has not decreased, for the methods now in use, which permit of saving more of the coal than formerly, other apparatus of great power and capacity. The elevation of material and the pumping of water, highly charged with acid, from the working levels approaching 1000 feet below the surface, are beset with difficulties, and when the daily duty is measured in thousands of tons of coal or refuse, and millions of gallons of water, the problem demands massive and efficient machinery.

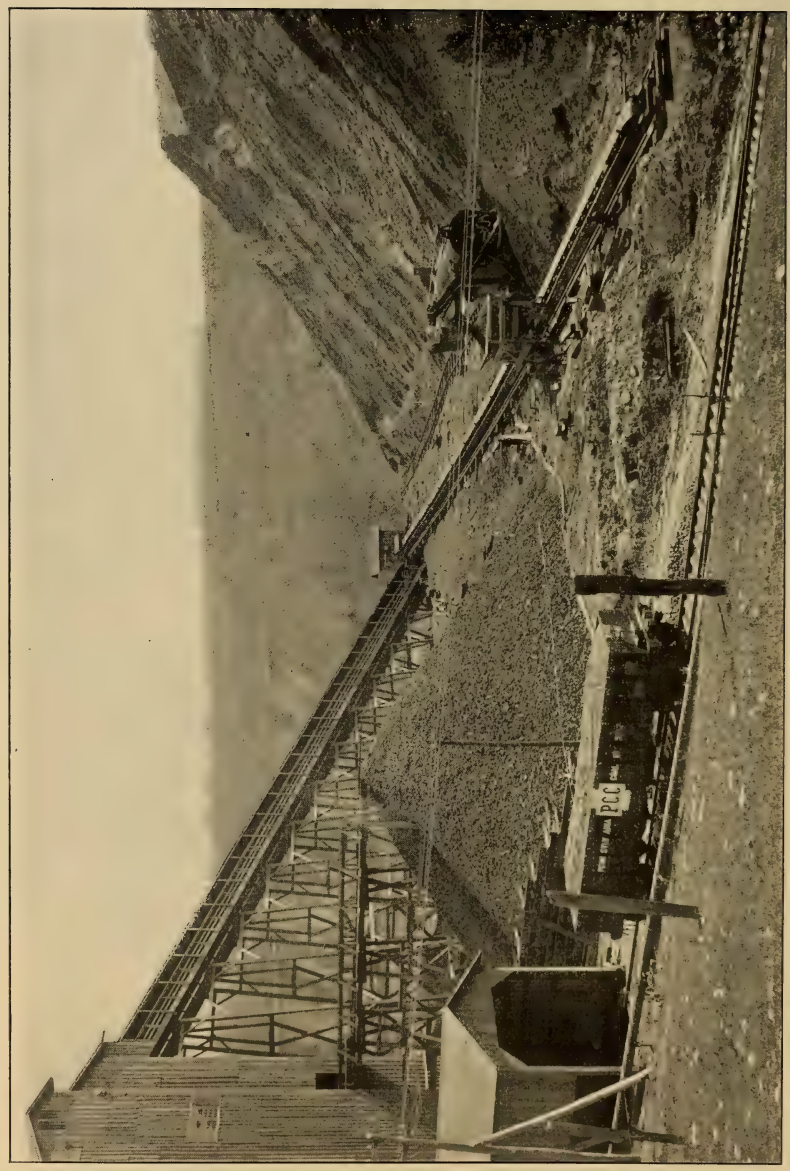
The extent of the underground workings, the ramifications due to the pitch and strike of the various veins, and the quantity of gas that is met with in some of the mines, required the highest skill in devising means of ventilation, and powerful fans to maintain this. In the treatment of the coal and its preparation for market the engineer has supplied excellent breakers of enormous capacity, and since the mining laws of Pennsylvania have demanded that coal breakers be removed from the mouths of shafts or slopes the construction of these breakers has embodied many improvements. At numerous locations the consolidation of adjacent mines has

A GROUP OF SLATE PICKERS

add to the value of the mining properties, while later additions to mining and coal-treating appliances represent large outlays for equipment

The mechanical appliances used embrace all variations, from crude and inefficient machinery to model types of hoisting, pumping, ventilating, and permitted the introduction of appliances the use of which would have been problematical when each colliery maintained separate equipments and superintendence.

One of the Pennsylvania breakers is unique in the arrangement for handling coal. The mineral raised in a shaft 200



WORKING CULM BANKS WITH A STEAM SHOVEL AND A BELT CONVEYOR MADE BY THE ROBINS CONVEYING BELT COMPANY, OF NEW YORK.

A MINE CHAMBER PARTLY FILLED WITH CULM, FLUSHED IN THROUGH A PIPE FROM THE SURFACE

feet deep is lifted 150 feet above the surface in a steel tower, in the cars which receive the coal at the mine breasts. Arriving at the top of this tower, the mine cars dump automatically into a chute which conveys the coal by gravity to the crushing rolls. At other breakers the approximate angle of the mine slope is continued to the top of the breaker, and at others still the mine cars traverse surface tracks leading from the shaft mouth or slope mouth to a point where they are conveniently raised to the crushing rolls.

The anthracite coal region has had its full share of disasters. Human life has been sacrificed in extensive fires, disastrous explosions, serious caves and squeezes, and in useless conflicts between labour and capital. Its proximity to the Atlantic seaboard has encouraged the addition to its local peaceable labour force of an element which, during temporary residence, has been responsible for most of the disorders which have masqueraded under the guise of protecting the workingman. It has a notable list of heroes who have risked and, in many cases, given their lives to save those of fellow workmen, or to recover the bodies of victims of mine disasters.

In addition to the examples of mechanical ingenuity and constructive skill which abound at the different collieries, the mining of anthracite coal has, as before noted, called upon the civil engineer for the solution of difficult problems in railroading, including inclined planes upon which cars are hoisted by powerful machinery, and also in the construction of important canals. Most of the latter have passed into the control of railway companies and have been practically abandoned. These means of transportation give outlets for the coal mined, which, after being delivered by through lines of railway or upon open water courses, reaches points of consumption or distribution, and at the latter some excellent examples of coal storage have been constructed. The North Atlantic seaboard cities and the prominent ports on the lower Great Lakes have some notable coal handling appliances, and the same may be said of the ports on Lakes Superior and Michigan, where large coal receiving docks and storage facilities are provided, some of which are covered. An example is illustrated on page 513, to show the general construction of the large buildings provided at West Superior, Wisconsin, for storing anthracite coal. These structures are claimed to be the largest domes in the world. They are 250 feet in diameter and 100 feet high, and each has a capacity to store 50,000 tons of anthracite coal, which is delivered to or taken from the buildings by conveyors. During the year 1900 the shipments of anthracite coal to the head of Lake Superior.

THE END OF THE FLUSHING PIPE

RICHMOND COLLIERY AND COAL BREAKER AT SCRANTON, PA., U. S. A.

amounted to 515,515 net tons. This coal was carried fully 300 miles by rail and 1000 miles by water, and was distributed from the storage piles to the northwest section of the United States.

Burning without smoke, a large proportion of the anthracite coal mined in Pennsylvania is distributed for domestic uses, with the result that the demand is at a minimum during warm weather, when the collieries are operated for only two or three days per week, thus reducing the miners' earnings to a bare living, and destroying all operating profits.

A partial effort to equalise the exploitation of the anthracite mines has been made by the establishment of storage yards, and by offering coal to consumers at such reduction as will encourage them to store a maximum of stock in the warmer months. This practice, if extended, seems to offer advantages in excess of its cost, as regular operation of the collieries would be a most desirable attainment.

This sketch of the anthracite coal fields of Pennsylvania could be extended by giving details of the methods of mining, examples of hoisting, ventilating and pumping machinery or of the crushing, screening, and picking devices of various breakers. It could be made to embrace the story of fortunes won and of fortunes lost, of terrible disasters by gas explosion, by fire, or by crushing of supports, relieved by deeds of heroism on the part of those who sought to rescue the injured or to recover the dead. It could include the sanguinary history of the "Molly Maguires," when murder was done by order, and of later strikes and riots by which property and life were sacrificed. It could embody interesting geological data, the result of study of masters in this science, and illustrate remarkable fossils which have been exposed to view. But space limits have here prevented attempting more than the general statements given.

THE METRIC SYSTEM

A PRACTICAL VIEW OF IT, AND A SUGGESTION

By E. Sherman Gould, M. Am. Soc. C. E.

IT is probable that the public at large, and even to a great extent the technical professions, have not given much attention to the fact that a bill has been lately introduced in the United States Congress for the adoption of the metric system of weights and measures in the United States. This system has been already legalised in America, so that anyone is at liberty to use it in any transaction involving weights and measures, but the present bill appears to contemplate its formal adoption as the standard system of the United States, to the exclusion of the present one.

In the question of the relative merits of the metric and English systems, the advocates of the former base their arguments mainly upon the greater ease and simplicity with which arithmetical calculations can be performed by it. This advantage must be generally admitted, and furthermore that the metric is the most perfect and consistent system of combined weights and measures ever devised.

But ease and simplicity of calculation, important as they are, are not the only qualifications which a measurement system should possess, nor, the writer ventures to assert, are they the most important ones. You must first take your measurements before you can record them, and before you can add, subtract, multiply and divide them. There are, to use engineering language, both the field work and the office work, and the writer believes most practical men, —the men who actually use the measuring instruments,—will agree with him that ease and accuracy in field work should always take precedence of ease and simplicity in the office work. The first essential is to facilitate the laying out of the work and measuring it up, leaving the mere manipulation of the data, on paper, to the greater leisure and facilities of the office, where mistakes, if made, are more easily detected and rectified. In other words, facilitate the convenience and accuracy of the artisan rather than of the computer.

Sometimes the consideration of antecedents helps us to judge of the merits of an existing status. Let us, therefore, remember that the English system of weights and measures is the result of the natural selection of the great practical, mechanical and industrial race of mankind, developed by, and meeting the needs of, the creative artisan working with the measuring rod in one hand, and the saw, the hammer or the chisel in the other. The metric system, on the other hand, is the scientifically beautiful conception of a coterie of savants who probably never in their lives had occasion to make a single practical measurement. Scientific consistency was aimed at, and we may readily believe that the practical convenience of the artisan was not once thought of.

It was considered of more importance that the system should derive an august parentage from the arc of a terrestrial meridian,—preferably that of Paris,— than that it should be the adaptation of means to a practical end. Hence the meter was taken as the unit. If the artisan needs something smaller, let him take the thousandth part of the unit and call it a millimeter; if the surveyor needs something larger, let him take it a thousand fold and call it a kilometer; but never let either lose sight of the unit; never let him relax his hold on the meridian of Paris, right or wrong. The charge is constantly brought

against the English system that it is complicated. Taking linear measurements, the partisans of the metric system tell us we have the inch, the foot, the yard, the fathom and the mile. How confusing, they say. Why have several tools, instead of only one?

The answer is, because we have several different kinds of work to do, and we need a convenient tool for each. The handicraftsman uses the inch, which he subdivides into halves, quarters, eighths, etc., according to the natural method of successive halving. He will run up to 100 and more inches before giving up his unit for a larger one. The builder and architect need a larger unit, and takes the foot, which he subdivides, usually, duodecimally into inches. The sportsman finds the yard, which he can measure by stepping, the most natural and convenient. The line engineer takes the "station" of 100 feet as his unit, and for long distances between localities the general public adopt the mile. All, be it noted, follow the instinctive tendency of the practical man to use multiples of smaller units rather than divisions of larger ones.

"But," the metric advocates reply, "we do the same. We use the millimeter and centimeter for small measurements and the meter and kilometer for larger ones." So they do, but with this radical difference,—they use exclusively decimal divisions and multiples, irrespective of whether or not the outcome is the convenient unit sought after.

In the English system the convenient unit is secured, irrespective of the ratio which it bears to the one above or below it, provided that some simple ratio does connect them. One-twelfth of the foot is more convenient for small measurements than one-tenth, which is rather too large. Three times the foot is more convenient for many uses than ten times the foot, hence the yard; and 5280 times the foot is just about right for the unit of geographical measurements; hence the mile.

Moreover, we freely use decimals of all the above units when it becomes more convenient to do so. As already stated, the line or railway engineer uses stations of 100 feet, and expresses his "plusses" in feet and decimals of a foot. Levelling rods are graduated to feet, tenths and hundredths, and are read to thousandths by means of a vernier. Engineers' draughting scales are divided into inches, and tenths, twentieths and other even multiples of ten.

In land measure, areas, whether measured with the 100-foot or 66-foot chain, are now always expressed in acres and decimals of an acre, and so on. In a word, throughout the whole system the convenience, and, consequently, the accuracy, of the one actually making the measurements are consulted, rather than of the computer who only figures them up, the fact being recognised that there is not, and cannot be, any single unit which is equally convenient for all uses.

The writer believes that this is the true view to take of the subject. He believes that the more it is studied, with the measuring rule in hand, the more it will become apparent that the English system of linear measurements is wonderfully adapted, by its very variety, to the various uses to which it is put by the dominant industrial race that invented it. No doubt it involves some inconvenience in the office; but it is typical of the spirit of its inventors that this defect is lightly considered if it is the price paid for greater convenience in practical applications.

Let anyone who is interested in this matter procure a pocket rule, such as is easily obtainable from dealers in such articles, graduated to inches on one side and centimeters on the other. Let him then take a number of measurements, and he will see how much more readily and certainly the inches are read than the centimeters. This is largely due to the fact that the greater length of the inch admits of each one being marked on the rule with its number, while on the centimeter side only the even decimeters are numbered. Consequently, when reading a measurement on the metric scale, it is necessary to look back to find the mark of the nearest decimeter and add to it the suc-

ceeding centimeters and millimeters.

For instance, take a distance measuring about 15 inches! On the metric side of the rule you must first find the 30-centimeter mark to the left, and then follow along for a distance of several inches to find the odd centimeters and millimeters. Again, take a distance of about 15⅞ inches, or 19¾ inches, and notice how apt one would be to read it incorrectly on the metric scale.

It is probably owing to this fact that the millimeter is used so extensively as the unit for even quite considerable lengths by artisans employing the metric system. The above suggestion to give the two systems a fair practical trial by actual use will prove, I believe, a veritable "eye-opener" to many who have advocated the metric system simply on general or academic grounds.

There remains the question of facility in dealing with foreign nations, irrespective of the practical merits of the two systems. This is a feature of the subject which calls for the most serious consideration. The existing Babel of weights, measures, and monetary values is most detrimental and embarrassing in international negotiations. It ought not to exist, and it would be well worth while to make considerable sacrifices to secure uniformity in these respects. This is the strong point in favour of the adoption by Great Britain and the United States of the metric system, pure and simple. Though failing, as the writer thinks, in many practical requisites, it is still conveniently applicable to many uses, and as an harmonious whole it would be hard to beat. Moreover, it is in actual use in many different countries; perhaps in the aggregate it is employed by a greater number of people than any other, the next most extensively used being, of course, the English system. This much may certainly be said in its favour.

It is worth while to consider closely what it is that occasions the inconvenience when one nation uses one system and the other another. In final analysis it will be found that this inconvenience is serious only when there is no exact equivalent between the two; that is, when there is no unit in the one which is exactly equal to a unit in the other, or is not at least connected with it by a simple and exact ratio. Now, no such equality or ratio exists between the metric and English systems. The United States has legalised 39.37 inches as the equivalent of the meter, and the British Weights and Measures Act of 1878, 39.37079 inches, the exact conversion of one to the other being impossible. If by a happy inspiration the French meter had been made exactly 40 English inches, the confusion of linear measures would have been almost wholly avoided. We would

PROPOSED CENTIMETRIC DIVISION ON THE BASIS OF A 40-INCH METRE.

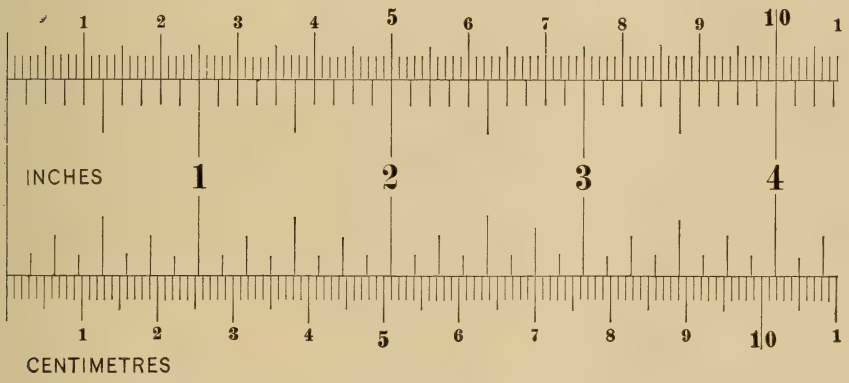


DIAGRAM ILLUSTRATING THE RELATION OF THE METRIC SCALE TO THE INCH SCALE

then have had the following exact equivalents:—

1 inch = 2.50 centimeters
1 foot = 30.00 "

The two systems of linear measurements would have been interchangeable, and, therefore, practically the same, except in name. Thus, to convert centimeters and decimals of a centimeter into their exact equivalent in inches and decimals of an inch, multiply by 4 and divide by 10; that is, multiply by 0.40. Reciprocally, to turn inches and decimals into their exact metrical equals, multiply by 2.50. Meters would reduce to feet and decimals by dividing by 0.30, and to feet and inches by multiplying by 40 and dividing by 12. If, besides, the inch were subdivided decimally, it could be truly said that the two systems were really identical except in name. The inch would be exactly 25 millimeters, and if divided into hundredths, the millimeter would equal 4 "centiinches." Certainly, in this case, "It might have been" are very sad words.

The diagram on the preceding page illustrates graphically the relation of the metric scale to the inch scale. The central portion of the figure shows a scale of inches, divided on its lower edge into halves, quarters, and eighths, in the usual way. Just below is the metric scale, with its usual subdivisions of centimeters and millimeters. On the upper edge of the central scale the inches are divided into tenths, as in an engineer's draughting scale. Just over this is shown the metric scale as it would be if the 40-inch metre were adopted. It clearly shows the perfect agreement which would exist in that case between the two systems. If the inch were divided into fiftieths, each fiftieth would exactly equal half a millimetre.

The writer has endeavoured in the preceding pages to consider, from its purely practical side, the question of giving up the time-honoured "foot-rule." The unification of measurements the world over is a great desideratum, which is well worth being considered, but the abolishing of the inch from the workshops of Great Britain and America is a serious matter which also merits consideration. Indeed, the question might be raised whether the French mechanic would not be benefited by the adoption of the inch by his government, for the writer is convinced that for all mechanical arts and machine work, where lengths are of necessity relatively small, the inch is by far the handiest unit.

The ideal condition would be realised should France and the metric nations generally change the meter to an exact 40 inches. The change seems slight, but would be a very grave one, for it would affect weights and values, as well as linear measurements, and any change, even the smallest, in such matters is revolutionary. The final result would be, probably, the general adoption of the inch in the machine work and mechanical arts of the world, and of the meter and decimals for long distances. The kilogram would replace the pound. Meanwhile, the existing English system and the reformed metric system would be readily interchangeable.

If any international unification of weights and measurements, by mutual consent, should be adopted, it should be extended to money values also. By giving and taking, five American dollars should be made exactly equal to twenty-five French francs and to one pound sterling, and the last named should be divided decimally. In that case, the American five-dollar gold piece or greenback, the French twenty-five-franc piece, if coined, or its paper equivalent, and the English sovereign or Bank of England five-pound note, would represent the same value the world over.

PREVENTING ACCIDENTS IN ENGINEERING WORKSHOPS

THE AMSTERDAM MUSEUM OF SECURITY AND THE FRENCH AND ITALIAN ASSOCIATIONS OF EMPLOYERS FOR THE PREVENTION OF ACCIDENTS

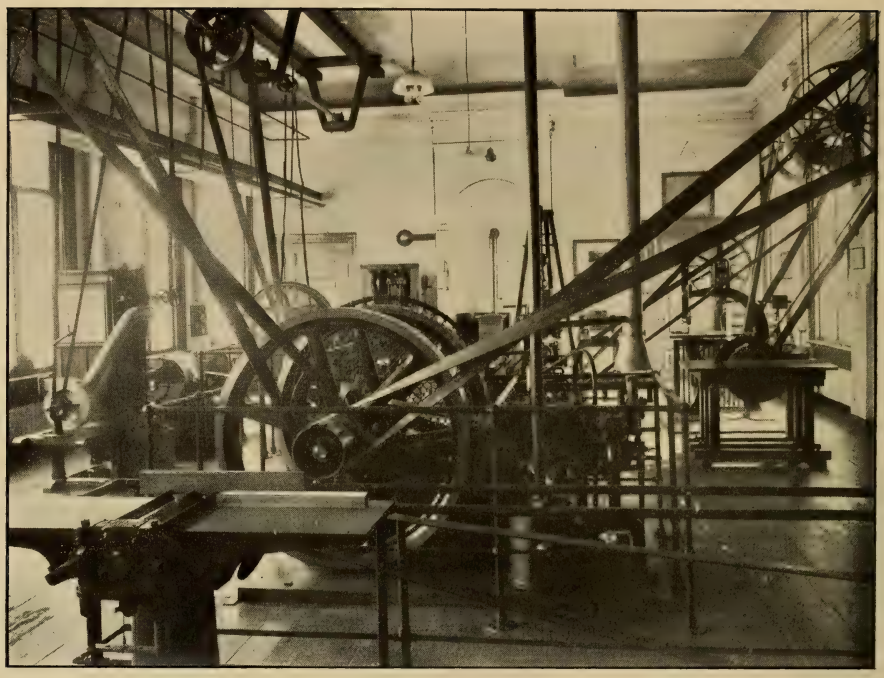
By William H. Tolman, Ph.D.

The illustrations accompanying Dr. Tolman's article are left to speak for themselves. With the exception of the two views of the Amsterdam Museum of Security, they represent a selected few of a very large number of devices of various kinds exhibited at the institution, and help to give one a fair idea of the character of the collection.—THE EDITOR.

THE MUSEUM OF SECURITY AT AMSTERDAM, HOLLAND

THE Amsterdam Museum of Security owed its origin to the Association for the Development of Manual Training and Manufactures in Holland. In 1889 there was connected with this association an advisory commission which proposed an exposition of all kinds of models to promote the purpose of the association. At the same time the commission reserved for itself the choice of the articles to be exhibited as a nucleus for a future museum. This exposition, held in Amsterdam in 1893, was an immense success, and awakened the interest of the entire country which immediately recognised its economic importance.

At the close of the exposition the Amsterdam section proposed the foundation of the "Museum of Security," and placed there fifty of the objects exhibited. These formed the beginning of



AN INTERIOR VIEW OF THE AMSTERDAM MUSEUM

the museum, which was in charge of a committee of twelve, who requested contributions from the State, the city, and from individuals. The State gave them annually £250; the city of Amsterdam gave the building for the museum, while individuals contributed the balance. In addition, about £170 of the profits of

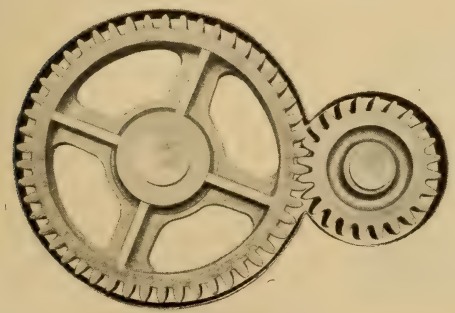
SAFETY SKIDS FOR HEAVY LOADS

the above-mentioned exposition were given to the museum.

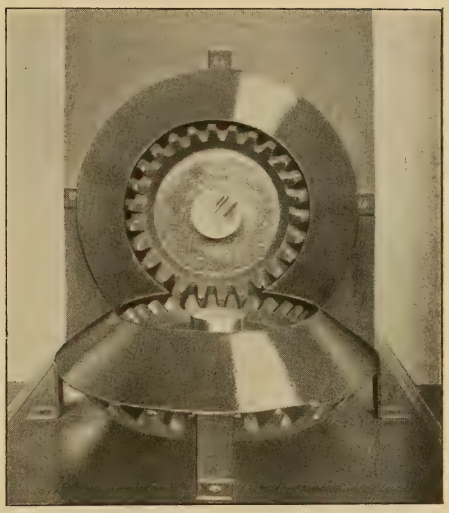
As to the best method of organising the museum, it was decided that it should be an object lesson as much for the employer as for the workman; that there should be as large a number as possible of models of the size in actual use in factories and workshops; and that the machines and appliances provided with safety devices should be in daily operation in order that manufacturers and superintendents might see how they worked and understand their value. The museum was opened in 1893 under the care of a mechanical engineer, A. C. M. Van Etten, charged with the supervision of the machinery and also of giving explanations to inquirers. The museum is open, free to the public, four days in the week, and on the first and third Sunday of each month. The number of visitors is increasing, and testimonials are received from foreign countries commending the efficiency and usefulness of the undertaking.

The labour inspectors of Holland find that the museum is of great service to them because it meets every objection on the part of a superintendent that a proposed safety device will interfere with the proper operation of his machinery. If the manufacturer is not satisfied with the photograph of the appliance which the labour inspector may show him, he can send his superintendent or go himself to the museum, where he can study every detail of the operation. One room is fitted up as a library, filled with books on hygiene, sanitation, industry, and social economy.

In the centre of the main hall there is



PROTECTED SPUR GEARING

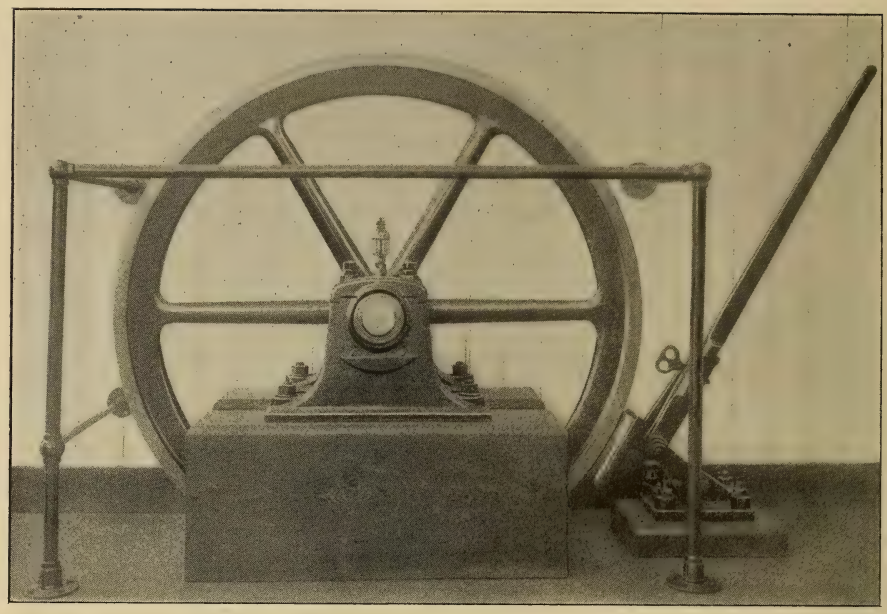


BEVEL GEAR GUARDS

a 6-H. P. gas engine for driving printing presses, looms, circular saws, planing machines, grindstones, and a dynamo. The dangerous parts of all these machines are safeguarded by means of the latest devices; one very simple precaution is the painting red of those particular parts. The dynamo drives many of the machines and also operates the ventilating system. All the electric circuits are provided with automatic shut-offs of the current for stopping the motor. Safeguarded models of gearing, belts, wheels, elevators, windlasses, cranes, staircases, fire escapes and shafts are displayed.

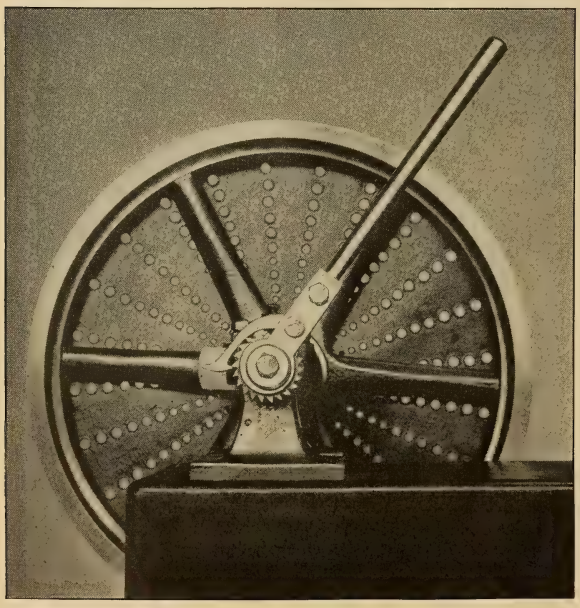
In another part of the museum scaffolding has been constructed for the sake of showing how this may be built so as to best protect the workmen. Side by side are different systems of scaffolding for a variety of buildings. One of the rooms contains a workshop of half the natural size, equipped with approved systems of ventilation for disposing of noxious vapours or gases liberated in different lines of manufacture, such as making white lead, and for removing dust in the preparation of flax, rag picking, grinding operations of various kinds, brush manufacturing, and others.

There are, too, all sorts of appliances for rendering as harmless as possible the



A FLYWHEEL TURNING GEAR

use of acids, the latest forms of lamps for use in mines, devices for protecting the faces and eyes, respirators, the most serviceable material for workingmen's clothes, cases for dressings and drugs for emergency use in accidents, fire extinguishers of all forms, and appliances for rescue in case of a conflagration.



A GAS ENGINE STARTING GEAR

As indicating how such a museum serves as an object lesson outside of Holland, the city of Toronto, Canada, sent Louis Guyon, the chief of its department of factory inspection, to the Paris Exposition to study the latest methods of accident prevention. He informed the writer of his great interest in the Amsterdam Museum, and that he had found it so practical that he had succeeded in obtaining a fund of $1000 from the manufacturers of Toronto for the purchase of models to bring back to Canada.

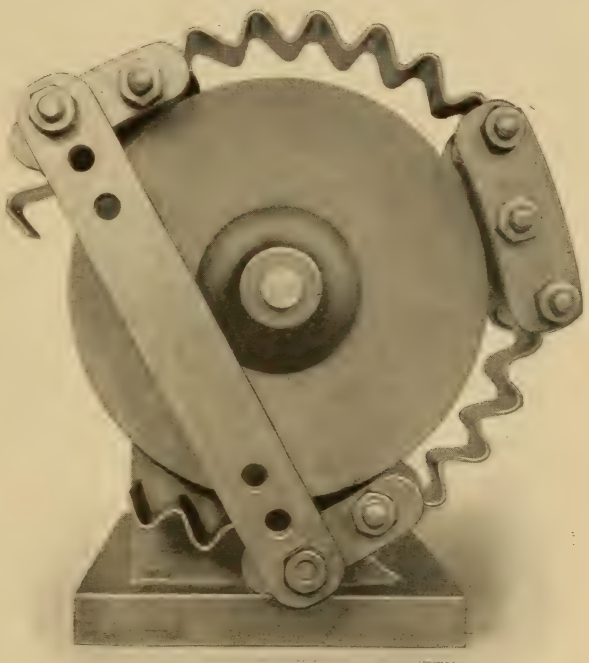
A report of the number of accidents in Germany for 1896 shows that out of 349,388 accidents 6939 caused death, 1524 permanent incapacity, 44,373 partial incapacity, while in the case

of the balance the injured were able to return to work after recovery. At the International Congress held at Berne in 1891, M. Engel-Gros reckoned the total number of annual accidents in the industrial world at 1,000,000.

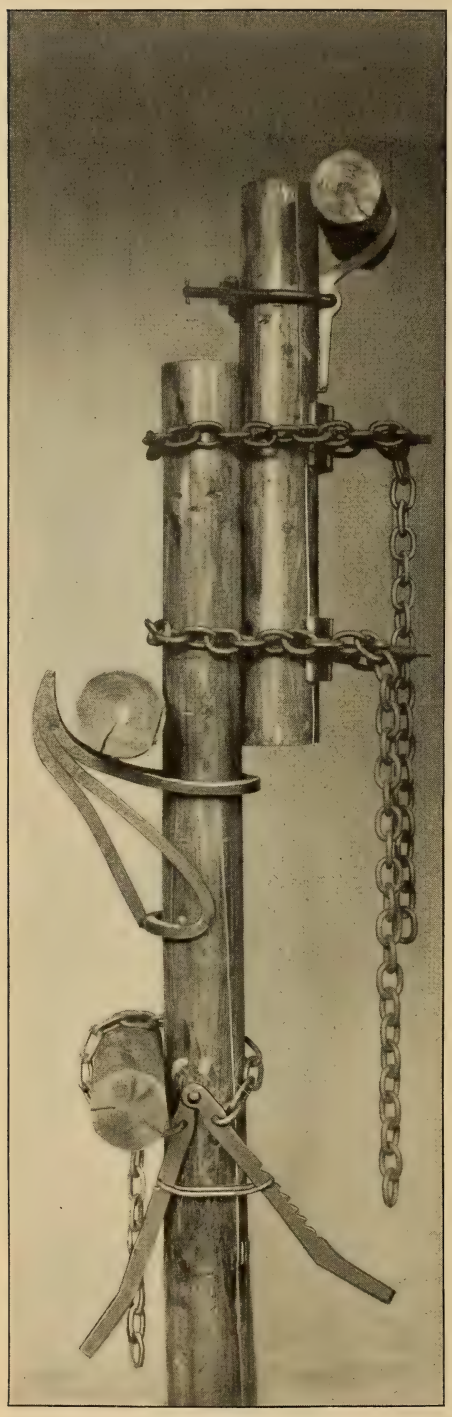
For a long time accidents in industrial pursuits were considered as practically unavoidable. It was maintained that a large number of accidents were altogether beyond human prevention, because they were due to blind chance, to some superior force, or the result of some mistake which put to naught any previous precaution. Accidents were so frequent that manufacturers began to think they were inevitable and that their duty only concerned lessening the disastrous after-effects. To-day there is a more just appreciation of the matter, and it can be clearly shown that nearly 50 per cent. of the accidents can be avoided by precautionary measures if wisely taken. If, therefore, it is wise to make reparation after an accident, it is still wiser to prevent the disaster. The moment the efficacy of preventive measures become known it should be the duty of the employer to apply them just as widely as possible in his factory.

In France the Association of Employers for the Prevention of Accidents to Workmen was formed in 1883 on the initiative of the Society for the Protection of Apprentices. Its first operations were in the immediate vicinity of Paris, but its action was so beneficent that it grew until to-day it has 2700 members, employing 280,000 workmen in seventy-one out of the eighty-six departments of France. In the chief industrial centres it has its own corps of inspectors, who examine factories and workshops. In consultation with the employer they suggest such measures of protection as can be applied with the least inconvenience to the work in hand and at the least expense. The inspectors may be considered consulting engineers in the matter of accidents. The employer who joins the association is free to withdraw at any time, and has no other obligation than paying an annual fee based on the number of workmen in his employ. The table on the next page shows what these fees amount to.

According to the constitution, the objects of the association are, first, a prevention of accidents in the use of machines, in physical or chemical operations, and in the various shops where structural work is done. Second, seeking the most effective means of tabulation, for instant reference, of the successful experience of the members and placing it at the disposal of others, such as the periodical inspection of their factories and workshops, communicating the best methods of protecting the workmen by indicating the best rules for the regulation of the workroom, and by



AN EMERY WHEEL GUARD



A SPECIMEN OF SAFE SCAFFOLDING

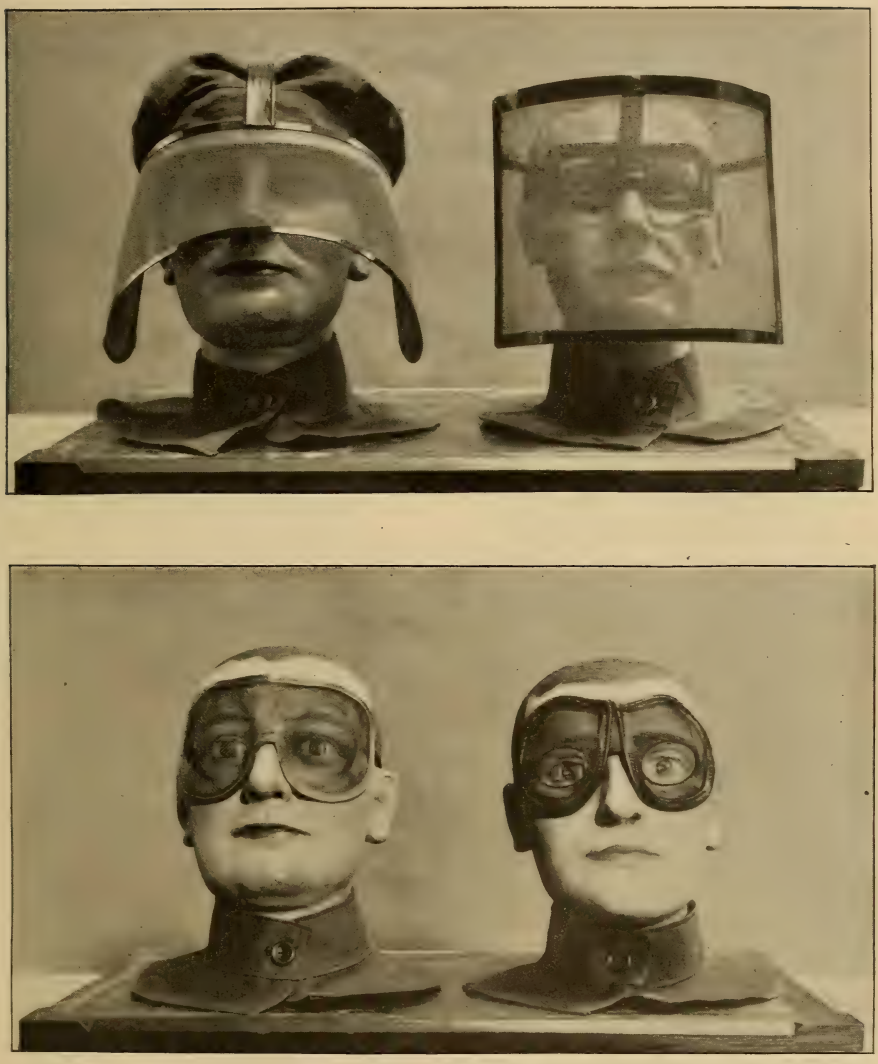
publications concerning the law and its operation on industrial matters. Third, to recompense, by prizes or other awards, those who, by the invention of appliances, by means of any new process, or by the practical application of any device in their own factory, have contributed to the lessening of accidens and the best sanitation of their establishments.

FEES TO THE FRENCH EMPLOYERS' ASSOCIATION

Number of Workmen			Annual Fee
1	to	10	10 Francs
11	"	20	20 "
21	"	40	30 "
41	"	55	40 "
56	"	70	45 "
71	"	85	50 "
86	"	100	55 "
101	"	125	65 "
126	"	150	75 "
151	"	175	85 "
176	"	200	95 "
201	"	225	105 "
226	"	250	115 "
251	"	300	130 "
301	"	350	145 "
351	"	400	160 "
401	"	450	175 "
451	"	500	190 "
501	"	550	205 "
551	"	600	220 "
601	"	700	240 "
701	"	800	260 "
801	"	900	280 "
901	"	1,000	300 "

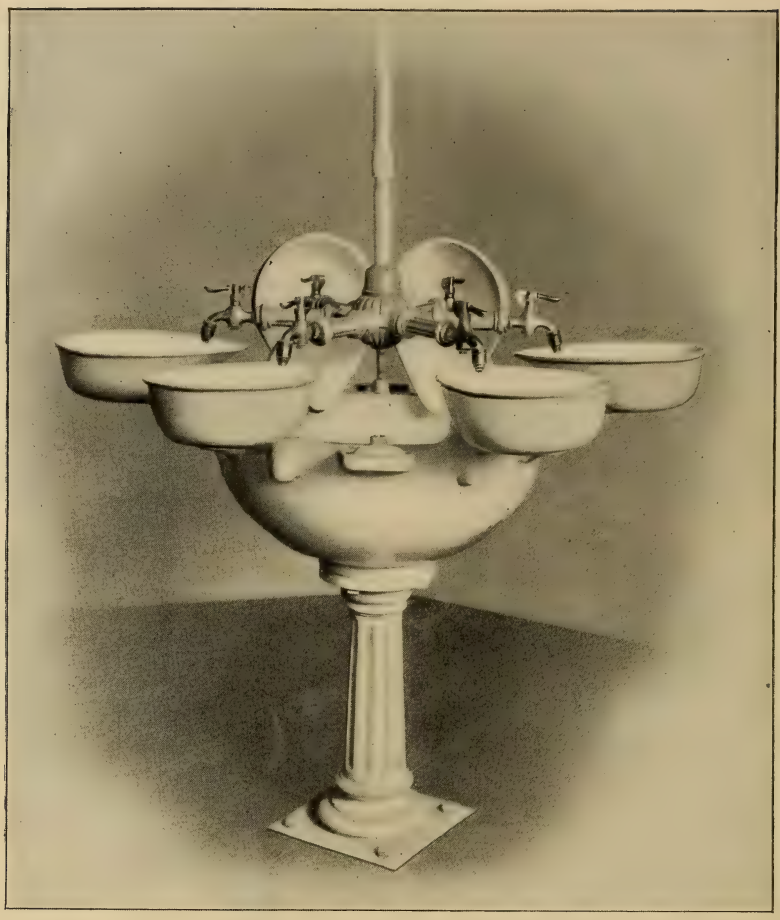
The association elects a committee of thirty members, representing different industries, private and public. One-third retires every year, but may be re-elected. An executive committee of seven to ten members is chosen by the Council of Direction. This council, on the proposal of the executive committee, appoint the inspectors, fix their salaries, and arrange that each establishment in the association be visited at least once a year, or as often as may be necessary. The committee serves without pay, but compensation is voted to a member who gives special time and direction to assigned work. The inspectors, as far as possible, are engineers. They cannot make an inspection unless accompanied by the superintendent or his representative. In their inspection they must do nothing but what is dictated by the fulfillment of their design with the utmost loyalty and the greatest discretion.

The chief advantages of membership are, first, the availability of means of reducing the number of accidents, the reduction having amounted, as shown by experience, to as much as 40 per cent.;



EYE AND FACE PROTECTORS

second, promoting, as a natural consequence, the security of the workers; third, the creation in favour of the employer of presumptive evidence of his caution and foresight which will tend to a more favourable consideration of the accident case when brought into court; fourth, a progressive lowering of accident insurance premiums, resulting from the lessened risk of accidents. Among the publications of the association is a book of " Instructions for the Starting and Stopping of Motors of all Kinds "; another on all sorts of saws, especially circular saws, for workers in wood, while frequent circulars inform the members of the text of new laws, with observations and the conclusions of the committee of direction on the law in question. Independently of these educational documents the association publishes an annual report on the scope of its work. It also furnishes to its members posters for use in workrooms regarding the use



A WORKSHOP WASHSTAND DESIGN

of dangerous machinery, with precautionary measures.

In Italy accident prevention among workmen had, until 1894, occupied the attention of only a very limited number of employers; but in that year, inspired by examples in other countries, they began a policy of installing and perfecting all kinds of factory protective devices. A collection of these was shown at the Exposition at Milan in 1894, and, somewhat later, the International Congress for the Prevention of Accidents to Workmen, which was held in the same city, attracted the attention of the industrial world to this matter, and contributed very materially to developing a sentiment in favour of striving in every possible way to lessen the chances of accidents.

Profiting by the occasion of the Exposition and the Congress, several of the Italian employers, under the presidency of Signor de Angeli, took the initiative in trying to unite the representatives of the movements interested in industrial betterment and organised the Association of Italian Employers for the Prevention of Accidents. This organisation was effected in November, 1894, and was shortly afterwards recognised by royal legislation as "an institution of public utility." In 1897 the government called its president to represent it in the Upper Council, the Italian legislators thus showing their confidence in

this action on the part of the employers to organise on their own initiative.

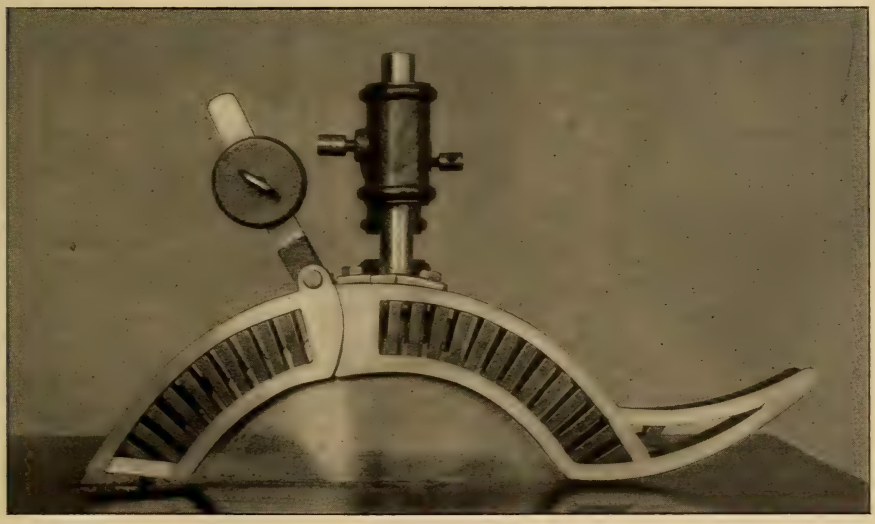
The object of the association is to study questions relating to the security of workmen during their labour, encourage and devise solutions of labour questions, and prevent avoidable accidents by the following means:—Periodical inspection of factories and workshops; devices indicating the most approved means for safeguarding the life and limbs of the workers; communications of special regulations in each branch of industry; publications on the subject of prevention; collections of designs and appliances to be placed at the disposal of the members; encouragement in every form for developing a sentiment leading to every possible safeguard, and also the designing of new apparatus.

When the association was established in 1898 it comprised 68 members, with 98 factories and 33,000 workmen. In 1899 there were 1130 members, with 1951 establishments and 277,512 workmen; 55,640 belong to cotton spinning and weaving; 18,025 to flax, hemp, and wool spinning and weaving; 133,000 to winding cocoons, silk spinning and weaving; 4163 to bleaching, dyeing and printing on textiles; 1354 to the leather industry; 1548 to the wood industry; 10,000 to metallurgy; 4688 to ceramics; 16,000 to chemical products; 3286 to food stuffs; 23,642 to other industries.

The resources of the association are maintained by an entrance fee and the annual dues, determined by the number of employees in each establishment, and ranging about as follows:—

Up to 50 workmen	10	Lira
From 50 to 100 workmen	20	"
From 101 to 250 "	40	"
From 250 to 500 "	60	"
From 501 to 1,000 "	80	"
Over 1,000 "	100	"

Once at least each year, and as often as may be necessary, the members of the association are visited by the inspectors of the society. A detailed report is made after each inspection and sent, signed by the engineer-in-chief, to the interested society. Each of these reports, which summarises the suggestions and advice for improving the conditions of the employed and the security of the establishment, is then indexed and so numbered that only the chief inspector knows which establishment is referred to. A copy of the report is kept in the archives of the association. The reports are almost always accompanied by the designs of the appliances which are suggested. For 1899 there were 1720 reports, 1581 plans and drawings, and 581 special instructions.



AN AUTOMATIC CIRCULAR SAW GUARD

On the initiative of other societies having the same humanitarian object, the committee of direction of the Italian society has recognised that it is very desirable for both employer and employee to see and study for themselves the various devices on a natural scale for safeguarding life and limb, and so at the central office in Milan a Museum of Security has been organised where it is possible to see in actual operation the machines fitted up with safety appliances.

The association publishes every year a report of its finances, and also a commentary on its technical work. Like other associations, it publishes a large number of pamphlets dealing with technical matters, such as the construction, installation and management of various machines, trying to be as practical as possible for both employers and employees.

Current Topics

A RATHER good, or bad, story has recently been told illustrating the arrogance, ignorance or whatever it may be called of the executives of some of the trades unions in dealing with their members. It appears that while a workman was engaged in guiding a cable into a conduit in a building that was being wired, his fingers were caught between the cable and the walls of the conduit. The men at the far end of the conduit, unaware of their comrade's plight, continued to pull upon the cable, seeing which an apprentice lad ran to his assistance and pulled back on the cable. A delegate of the union who had witnessed the affair and had expressed sympathy for the sufferer, reported him for violation of the rules of the order, and the latter was called to executive headquarters to explain his conduct. Notwithstanding that his fingers bore evidence to the extent of the accident he had undergone, he was fined "for allowing an apprentice to do helper's work, to wit, assisting a journeyman drawing wire into conduits."

PROBABLY everyone who has travelled in electric storage battery tramcars has been annoyed more or less by objectionable odours or irritating fumes from the batteries. In the city of New York, where one of the lines is battery-driven, the operating company has been cited to appear before the health authorities and show cause why their cars, as now operated, should not be declared a public nuisance, numerous complaints having been received and physicians'

reports having been made that the fumes in question frequently cause illness to passengers. In the battery cars on the Copenhagen tramways, in Denmark, the odours have often been so disagreeable that the passengers have got out to escape them. As to the probable cause, the following explanations have been given by three Danish engineers, Messrs. Paul Bergsoe, J. B. Bruun, and C. Kjoer. According to Mr. Bergsoe's opinion, as presented in the Foreign Abstracts of the British Institution of Civil Engineers, while no inorganic compound having the same odour can be formed from the contents of the accumulators, this is the odour emitted by deal which has been dipped in dilute sulphuric acid and laid aside for a time. It must, therefore, be due to the destructive action of the acid upon the resinous or other residue of the wood sap. The hydrogen liberated in charging the accumulator cells bubbles up to the surface of the dilute sulphuric acid; and the bubbles in bursting scatter microscopic drops of acid, which remain floating in the air for a length of time. The air thus impregnated attacks the woodwork of the chamber containing the battery and also of the car to which it has more or less free access. When the charging of the accumulators is approaching completion the evolution of hydrogen becomes so violent as to give the liquid the appearance of boiling.

In the accumulator cars for lighting the trains on the Danish State Railways the cells, according to Mr. Bruun, are set in leaden trays from which an outflow is provided. On an electric battery tramway worked experimentally for several years at Hagen, in Germany, it was endeavoured to get rid of the strong odour in the cars by exhaust ventilators connected with the battery chambers underneath the seats; but they were not powerful enough to prevent some of the fumes from penetrating into the cars towards the end of charging. To cover all the accumulators with air-tight leaden hoods, and draw off any vapours through a common outlet by a suction ventilator, would make examination of the battery difficult. Glass covers, on the other hand, would be liable to break.

Both hydrogen and oxygen, according to Mr. Kjoer, are given off from an accumulator towards the end of the charging, nearly in the volumetric proportion in which they form water, and both are impregnated with acid. A small quantity of oxygen also comes off as ozone, which has the peculiar penetrating odour noticed in accumulator cars. When the charging and discharging of the accumulators follow each other in quick succession with a strong current, the temperature in the battery chamber rises considerably above that of its surroundings. On the Berlin and Charlottenburg tramway it is always over 30° C., or 86° F., and in the warm season from 60° to 65° C., or 140° to 150° F., have been registered. Acid settling upon the sides and bottom of the chamber soon becomes concentrated by the combined heat and draught, and attacks wood so strongly that in a couple of months it looks as though it had been partially charred throughout its entire thickness. However carefully the chambers are protected with acid-proof linings of insulating material, the acid penetrates through the minutest crevices, and when once it reaches the wood there is no stopping its destructive action and the consequent liberation of odorous organic compounds. The ebonite cells ordinarily used for tramway batteries can also contribute to the odour. Their surface is attacked by ozone, and in time they themselves become hard and brittle. Hanging the battery under the car, whereby the objectionable odour would be completely obviated, has been tried elsewhere, but abandoned, owing to want of sufficient room for battery and motors together; moreover, the motors might then be attacked by the acid, whilst the battery would be inaccessible for examination after charging, unless complicated and expensive arrangements were specially made. As an inside bat-

tery requires removing of the cover for every charging, it is scarcely possible to prevent some escape of air impregnated with acid; but the nuisance may be so far diminished as to be insignificant. Only ten to fifteen minutes are allowed for charging the North Bridge tramcars in Copenhagen, and the charging must, therefore, presumably continue almost up to the time of starting; whereas the charging ought to be finished and the battery chamber shut off from the car some minutes before starting, so as to allow time for the air in the car to get fresh. Blowing air through the battery chamber is the wrong way of getting rid of the vapour, which ought to be exhausted by suction.

It is well known that the electrical pressure necessary to break down an air space must be progressively, although not proportionally, increased as the length of the air space is increased. Thus, roughly speaking, 2000 volts will jump across an air space of 1-64 inch, while 25,000 will be required to break down an air space of ½ inch, and in the case of lightning discharges it is calculated that millions of volts are necessary to break down the air space that separates two charged clouds or the clouds and the earth. The resistance to electrical pressure of many insulating materials, such as rubber and certain oils and resinous compounds, is greater than that of air, so that it is feasible to employ a much thinner wall of these materials to withstand a given electrical pressure than could be done if air were the insulating medium, the ratio being at least 5 to 1 in favour of rubber compounds and oils. It has, however, been found in practice that after a certain thickness of insulating material has been reached, more especially in the case of cables in which the dielectric is of a fibrous nature, such as paper or cotton soaked in oils, the resistance to electrical pressure does not increase at all proportionately with further thickness of the insulating wall. One explanation of this is that under the heating process to which the material is subjected to expel its natural moisture, vacuous spaces are left when the material cools, and these spaces are measurably conducting. Another explanation is that the long continued baking necessary to expel the moisture from the inner layers of the insulating material when it exceeds a critical thickness has a detrimental effect upon the material of the outer layers, which is manifested in a reduced resistance to electrical pressures. In this relation it is interesting to note that recent reports concerning the underground cables designed to convey current at a pressure of 25,000 volts in connection with an overhead transmission line coming into St. Paul, Minn., U. S. A., described in an article on high-tension cables in the October, 1900, number of this magazine, show that these cables have given highly successful results. These results are the more satisfactory in view of the fact that this was at the time, and is yet, the highest pressure to which underground cables have been subjected under actual working conditions, and the most experienced cable engineers were not sanguine of a successful outcome of the experiment.

It has been the fashion during the past few years, and undoubtedly there have been many good reasons for it, to talk unremittingly of British backwardness and want of enterprise in the engineering trades. That this, however, is not justified to anything like the extent supposed by some, Mr. J. S. Jeans tries to show in one part of the recently issued report of the commission appointed by the British Iron Trade Association to inquire into the iron, steel, and allied industries of the United States. Mr. Jeans, as one of the commissioners, says: —"There are in Great Britain, to my knowledge, finer works in many branches of engineering than are to be found in the United States. America has probably no counterpart worthy to rank with the works of Armstrong, Whitworth & Co., whether at Newcastle-on-Tyne or at Manchester. This, however, is hardly

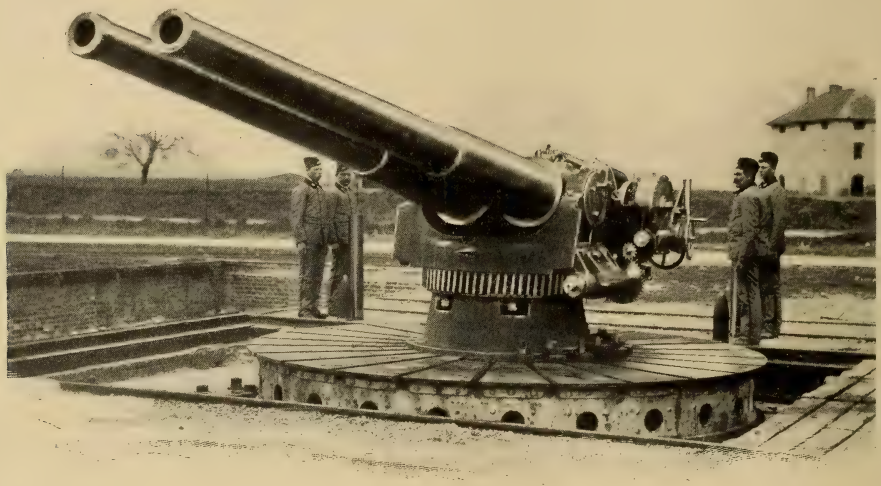
a concern that is typical either in their markets or in the character of their products. There are others. What American works can compare in their own special line with the works of Platt, at Oldham, and the works of Howard & Bullough, at Accrington? What American tube works are better organised than those of Stewart & Menzies, at Glasgow, apart from mere size? What pipe foundries excel those of the Staveley Company? What pump works can claim to be more up to date than those of Joseph Evans & Sons, at Wolverhampton? What locomotive works are better equipped than those of Neilson & Dubs, at Glasgow? And so in many other branches of the iron and engineering industries. Not only can Great Britain make claims for her principal works, such as those referred to, but those claims are likely to be emphasised by the new plants now being constructed to deal with those industries enumerated. The new works of the Westinghouse Electric Company, at Manchester, or of the Thomson-Houston Company, at Rugby, are cases in point; and at Rugby, also, are the magnificent new engine works of Willans & Robinson, of which it may at once be said that it would be hard to go one better.

"MOST of our great industrial centres," Mr. Jeans continues, "can claim similar model establishments. Those we have named are only put forward as types, not, of course, of the rank and file, but of the best of their kind, although they are far from being alone. Then, again, what lack of enterprise is shown on the part of the leading firms in the steel trade who have taken up the Talbot and Bertrand Thiel processes? At the time of my visit to the States only one firm had actually started the Talbot process, and none that I heard of had essayed the other. A second Talbot furnace was then being erected. In this country, the Frodingham, Dowlais and Weardale companies are adopting the Talbot process, and I am informed that two other firms are proceeding to install the rival process, while the Monell process has also been adopted on Tees side. The conclusion to be drawn from the recent attitude of British iron and steel manufacturers in regard to new improvements appears to me to be favourable to the future of those industries. Probably no authorities have taken greater pains to inform themselves as to that future, as liable to be influenced by American competition, than those who have been concerned in the recent consolidations in South Wales. Have these gentlemen sat down and folded their hands despondingly? Have they not been stimulated by what they saw and learned in the United States to take steps which implied a large amount of confidence in the future? And is not the same inference justified by similar action on the part of many other leaders of the trade, including those responsible for the destinies of that almost historic corporation,—the Weardale Steel, Coal & Coke Company?"

IT is so common a thing to read that fires of mysterious origin were doubtless caused by a defective electric light wire that it is something of a surprise to learn from recently published statistics on fire losses and causes for 1901 that out of a total of 30,800 fires in the United States but 1054 were traceable to electricity. On the other hand, the fires arising from this cause occasioned the highest average loss per fire. By far the largest portion of the fires causing losses, or about 66 per cent., were due to the use of coal in some shape,—defective flues, stoves, sparks from locomotives, furnaces, etc.

A MODERN revival of a double-barrel cannon idea, put into practice about forty years ago during the American Civil War, was brought out a short time ago by the famous French firm of Schneider et Cie, of Creusôt, and is illustrated on the next page. In a general way the picture tells the story best. The two guns are mounted on a single

carriage, and, being rigidly connected, are both aimed at once, though they may be fired either simultaneously or separately. While mounting heavy guns in pairs has been practised for some time on shipboard so as to accommodate two guns in a single turret, the guns in that case are independent and are aimed and manœuvred separately. The necessity for this has been avoided by Messrs. Schneider in the present design. Simplicity, compactness, a minimum distance between the two gun axes, economy in weight, and increased effectiveness of fire are the principal advantages claimed for it.



A MODERN DOUBLE-BARREL 6-INCH GUN

In describing a mechanical stoker for locomotives in a paper presented a month or two ago before the American Society of Mechanical Engineers, Mr. F. H. Colvin mentioned the rapid growth in size of locomotives and the consequently largely increased coal consumption as the primary things which have made such locomotive stokers worth having. The matter of coal economy is secondary to that of keeping the steam pressure at or near the popping point, so as to get the maximum work from the engine. The conditions of locomotive practice, Mr. Colvin said, among other things, are so different from those presented in the case of stokers for stationary boilers that they have seemed almost insurmountable, although much time and thought have been spent on them. These difficulties are not confined to the mechanical problem, for the selling of the locomotive stoker is an entirely different proposition from that in the stationary field. In the latter case it is an easy matter to show a marked reduction in labour cost, and this saving seems to appeal to buyers more than any other. In the case of the locomotive stoker there can be no reduction in labour cost, excepting in a few rare cases where two firemen are employed. This takes the cost of labour entirely out of the field, as it is not advisable to employ unskilled men on the locomotive equipped with a stoker, for in the event of the possible failure of the machine, the engine must be fired by hand until the end of the run. It is also necessary to train engineers, and the only practical way of doing this seems to be by having firemen work with engineers, as at present. The practical advantages of the locomotive stoker can be summed up as follows:—Increased work from the locomotive, due to maintaining a maximum

working steam pressure under all conditions of service; doing away with the necessity of constantly opening the fire-door and admitting large quantities of cold air into the fire-box, which opening tends to retard combustion and also has an injurious effect on the flue sheet; even distribution of coal over the whole of the grate, obviating thin spots through which cold air may be admitted, with results as injurious as when coming through the door, or even more so; and marked decrease in black smoke, due to the constant and steady firing, according to the demands of the boiler. Coal economy, however, is a natural outcome of the steady firing secured. Mr. Colvin, in his paper, gave illustrations and descriptive particulars, and also some general test results obtained in regular service with what is known as the Kincaid locomotive stoker.

It appears to be difficult to determine whether it is more economical, even in large cities, to operate an isolated plant for electric light and power, or to use a central station supply, so conflicting are the views held upon the subject and so admittedly indefinite is the information obtainable from those most capable of imparting that information. There is no doubt that the central station can develop electrical energy at a much lower figure than even a fair-sized isolated plant, perhaps at one-third less for coal alone, besides which the central station, as a rule, has a high load factor and improved facilities for economically handling coal and ashes, and thus has lower labour charges per kilowatt-hour than the isolated plant. There are, however, against these advantages the heavy losses in distribution between the switchboard at the central station and the consumer, which may be as high as 50 per cent. and rarely less than 20 per cent. It would at first seem that there should not be much doubt that the central station source of supply is cheaper than the isolated plant for small users of electrical energy, although even in this case the fact that the central station rate per kilowatt-hour is greater to the small user than to the large user is in favour of an isolated plant for the small user. Such statistics as are available show that savings have frequently followed the installation of comparatively small isolated plants. One thing that conduces largely to this result is that steam is necessary in a building for heating purposes, and thus, so far as the electric plant is concerned, labour charges are almost eliminated. The cost to the consumer of electrical energy from the central station supply, in American plants, ranges from four to fifteen cents per kilowatt-hour and that of the isolated plant from two to twelve cents per kilowatt-hour, with an average in the latter case of less than six cents per kilowatt-hour, depending on the conditions prevailing in each building. Where gas engines are employed to operate the dynamo the average cost per kilowatt-hour is somewhat higher. Notwithstanding these figures, however, the central station inspectors appear able to give convincing reasons why it is advisable to use their supply, as proved by the large number of isolated plants in some of the large American cities that have been shut down, their places now being taken by the central station supply.

Perhaps the most interesting series of papers read before the recent annual convention of the American Institute of Electrical Engineers were those upon the education of electrical engineers. Such papers were presented by professors of electrical engineering at several of the leading American colleges, by electrical engineers of some of the largest electric power stations in the world, and by men at the head of the students' departments in the large electrical manufacturing establishments. The papers, and more especially the discussions of them, disclosed the fact that very great differences of opinion are held by those most interested as to the best course to be pursued in educating young men for electrical engineering. One speaker, who has had a wide ex-

perience as a teacher, as a practising electrical engineer, and as the head of a large electrical manufacturing concern, expressed himself as distinctly opposed to imparting to the student anything but the fundamentals of the science, together with a broad general education, especially literature He would not teach Greek or Latin, except as literature, and considered the elaborate fitting of an electrical engineering laboratory in colleges a sheer waste of time and money. In his opinion also no one was qualified to teach electrical engineering but a practical electrical engineer. Equipped with a knowledge of the fundamentals of science, the student would quickly learn how to apply his knowledge when he began his apprenticeship as electrical engineer after leaving college. Other speakers pointed out that it was impossible to secure as professors of electrical engineering men who have been, or are, actually engaged in the work of electrical engineering, except in very rare instances. Others also spoke in favour of a well-equipped laboratory as the next best thing to actual electrical engineering work, to say nothing of the facilities for original research that such a laboratory would afford. There was no difference of opinion, however, as to the wisdom of giving the students a broader general education than has been the case heretofore, even if this should lead to a lengthening of the college course, now of four years' extent.

Recent comparisons between coal and oil fuel for ship use, based upon trials in the British Navy, appear to have shown that two tons weight of oil were equivalent to three tons weight of coal, and 36 cubic feet of oil to 67 cubic feet of coal as usually stored in a ship's bunkers. The saving of stokers was considerable. But the greatest commercial gain, in the mercantile marine, is the increase in weight and space available for freight. Thus, it has been figured out that if three tons of coal were taken as equal to two tons of oil fuel, there was a gain in weight of, say, 1000 tons in the freight of a first-class Atlantic steamer, and a gain of nearly the whole of the bunker space, which, subject to drawbacks of non-stowage in the hot parts, would be available for measurement freight. Allowing for these, and assuming the storage of the whole of the oil fuel in the double bottom and peaks, there would be a gain approaching 100,000 cubic feet of measurement made available for freight in such a vessel. The gain from substituting the new fuel in vessels of less steam power proportionate to the size would be correspondingly reduced, but it might be fairly estimated for most ships that 25 per cent. of the space now occupied by coal bunker storage could be utilised for cargo by the transfer of the fuel in a liquid form to the double bottom and other parts not now of any direct use. The cleanliness of oiling instead of coaling passenger ships and the saving of detention at ports of call are obvious advantages.

Two road rollers which have been in operation in France, in the Department of Seine-et-Marne, for the past two years, are noteworthy as representing what are probably the first successful practical applications of oil engines to this kind of work. The oil employed is that known in France as "schiste," and has a specific gravity of 0.805. It would appear, as the result of an extended trial which the rollers have undergone, that not only are the oil engines well able to work rollers, but they show a great economy, as compared with steam rollers. The framework, gearing, and other details of the rollers themselves were manufactured by M. Coutaut-Dujour, at Champeaux; but the engines, curiously enough, are of British make, having been supplied by the Dudbridge Ironworks, Ltd., of Stroud, Gloucestershire. They are of 16-horse-power, and they are mounted on a wrought iron framing carrying the driving gear, etc., much in the same way as in the case of the familiar steam roller. By means of a double friction clutch the

engine can be run in a forward or backward direction, as may be required. All the various levers and other moving parts can be operated from the cab, which is covered by an awning. A compressed air reservoir is provided for starting purposes, this being charged by the engine when it is at work.

ONE reason why a smoke consumer failed was thus set forth recently in the *Canadian Manufacturer:*—

"About a year ago," said a Chicago patent lawyer, "I secured a patent on a smoke consumer for a client of mine. He came into the office the other day, and I asked him what he was doing with his invention.

"'Well,' he said, 'I haven't had much success with it. It's hard work to get a thing like that introduced. Last spring, after a lot of arguing, I got a West Side laundry firm to try it, with the understanding that I was to take it out at my own expense if it didn't give satisfaction. After it had been in use a month or so I thought I'd go over and see how it was working.

"'As I approached the laundry I saw that there wasn't a bit of smoke rolling out of the stack. In fact, it was almost impossible to see from the outside hat there was a fire in the boiler. It made me feel mighty good to see that the thing was working so well, and I went into the office full of confidence.

"'"Well," I said to the senior partner, "how do you like your smoke consumer?"

"'"I've been going to write to you about that," he replied. "We want it taken out."

"'"What's the trouble?" I asked him.

"'"You agreed to take it out at your own expense if it wasn't satisfactory, you know. We have the contract in writing."

"'"That's all right. I'm not denying that I agreed to take it out; but I'd like to know what's the matter with it. I looked at it just now and it seemed to be consuming the smoke all right."

"'"Oh, it consumes, as far as that is concerned, but since the smoke has quit rolling out of the stack a lot of our old customers seem to think we've shut down here, and they're taking their laundry somewhere else."

"'"Yes," the junior partner added, "and I can't imagine where we ever got the fool idea that we ought to help stop the smoke anyway. It would be just as sensible for a saloonkeeper to go around preaching temperance."

"'So I had to take the consumer out, and I've decided to give up trying to introduce it among the laundries.'"

THE New York Court of Appeals has recently rendered a decision of interest to all who maintain or contemplate the erection of steel structures in the form of towers or high buildings. The case that has brought forth this interesting and important decision had its origin at Niagara Falls, and was instituted by Charles Davis against the Niagara Falls Tower Company. The latter company have an observation tower about 300 feet high, located a few hundred feet distant from the American Falls. Mr. Davis is one of the proprietors of a museum adjoining the tower, and the museum building has a glass roof or section. In winter the spray from the falls fell upon the tower steel work, where it congealed, and in times of thaw plunged down upon the museum, doing damage. It was this that led to the lawsuit, and the Court of Appeals decides that a responsibility confronting owners of tall buildings is the need of guarding against the formation of ice which, in falling, may damage property beneath. In this case it was decided that one who has erected a building at so great a height above an adjacent building as to cause the ice, which accumulates upon its sides and top each winter, to fall upon and injure his neighbour's building and endanger the safety of its occupants, may be restrained from maintaining such a condition. In the Niagara instance the ice formation was caused by spray drifting from the falls,

but the court held that rain is just as much a natural cause, and to all purposes the same.

THE action in question was brought to recover damages and for an injunction to restrain the defendant from so maintaining the tower as to suffer ice to fall therefrom on the plaintiff's property. The trial court had found that the injury to plaintiff's building and the accumulation and fall of ice from the tower on the plaintiff's property recurred each winter during periods of thaw. It further found that the tower was a safe, substantial and suitable structure for the purpose for which it was used. On these facts it decided, as a matter of law, that the maintenance and construction of the tower was a private nuisance, and that the plaintiffs were entitled to a perpetual injunction restraining the defendant from so maintaining the structure that ice would form thereon and fall on the building and premises of the plaintiffs. A reference was ordered to ascertain the plaintiff's damages. On the report of the referee final judgment was entered for an injunction and damages.

WASHINGTON A. ROEBLING

The Builder of the Brooklyn Bridge

A BIOGRAPHICAL SKETCH

AS an engineer Colonel Roebling's first work was in assisting his father, the late John A. Roebling, to build the Allegheny Suspension Bridge. This was shortly after graduation from the Rensselaer Polytechnic Institute, at Troy, N. Y., in 1857. Since that time international fame has been his as builder of the New York and Brooklyn Bridge.

At the beginning of the Civil War he enlisted as a private in the Sixth New York Artillery. He served with this battery for one year, and for the remainder of the war he was employed on staff duty. He was at Ball's Bluff with General Stone and on the Lower Potomac with General Hooker, fighting the Shipping Point batteries, during the winter of 1861-62. General Hooker's command was then transferred to the Peninsula, and after the evacuation of Yorktown Colonel Roebling was transferred to General McDowell's staff, and built a suspension bridge, 1200 feet long, across the Rappahannock for the use of the army. He took part in the pursuit of General Stonewall Jackson through the valley, and went with the cavalry reconnoissance to Louise county, returning to Culpepper, which he found in the hands of the enemy.

He was on General Pope's staff at South Mountain and Antietam through the campaign which ended in the second battle of Bull Run. During this time he built a suspension bridge across the Shenandoah, at Harper's Ferry. He was on duty at general headquarters during the battle of Chancellorsville. At this time he used to ascend every morning in a balloon to reconnoiter the enemy. In this way he was the first to discover and announce the fact that General Lee was moving off toward Gettysburg. He served on engineering duty in the Second Corps from August, 1863, to March, 1864, during which time he took part in the movement on Culpepper and the Rapidan, the combat at Antietam, the skirmish at Bull Run, and the battle of Kelly's Ford. He served on staff duty with the Fifth Corps from March, 1864, to January 1, 1865. In the Richmond campaign he was at the battles of the Wilderness, Spottsyl-

vania, North Anna, Bethesda Church, Cold Harbor, White Oak Swamp, the assault on Petersburg, siege of Petersburg, the Petersburg mine assault, Weldon Road, Peeble's Farm, Chapel House and Hatcher's Run. His last duty as a soldier was assisting in the destruction of the Weldon Road, December, 1864.

Colonel Roebling served with honour and distinction in the army of the Potomac, receiving three brevets for gallant conduct, and in January, 1865, he resigned his commission in the army and went to Cincinnati to assist his father in completing the Cincinnati and Covington Bridge. After his arrival there he took almost entire charge of the bridge work, from the spinning of the first cable wire until the last piece of the superstructure was in position. While the Cincinnati bridge was being constructed Mr. John A. Roebling was already busy with his plans for a bridge across the East River. As soon as he had finished his work on the Cincinnati bridge Colonel Roebling went to England, France and Germany to see and study up all that could be learned on the subject of pneumatic foundations, knowledge necessary before undertaking the difficult task of sinking the foundations of the East River Bridge. He remained one year in Europe, and besides inspecting all the important engineering works then going on there, he made a special study of the manufacture of steel, visiting the great works of Krupp at Essen, as well as the most important ones in England.

In February, 1869, he went to Brooklyn to live, choosing a residence as near as he could get to the work. While the caissons were being sunk he never left Brooklyn even for an hour, and at all hours of the day and night he visited the work going on under the water, and by his coolness, foresight and quick comprehension of the best way out of any unexpected difficulties, he several times averted a serious panic among the men when slight accidents and "blow-outs" occurred.

His excessive devotion to the work, joined with the fact that he spent more hours of the twenty-four in the compressed air of the caissons than anyone else, wore out his strength, and one afternoon in the spring of 1872 Colonel Roebling was brought up out of the New York caisson nearly insensible, and all one night his death was hourly expected by the anxious friends who watched by his bedside. In a few days he rallied, and was back on the work again. He was too weak, however, to labour as he had done before, and after the foundation of the new York pier was completed in July, 1872, he spent two or three weeks at Saratoga and Richfield Springs. He returned to the scene of his labours somewhat better after this little rest, but all the summer and autumn he was obliged to stay at home for a few days at a time.

In December he found himself too weak and ill to go down to the bridge any more. Fearing that he might not live to finish the work himself, and knowing how incomplete the plans and instructions for the completion of the bridge still were, he spent the whole winter writing and drawing, and the papers written while he was too sick to leave his room contain the most minute and exact directions for making the cables and the erection of all the complicated parts which compose the superstructure.

In the spring of 1873 the physicians attending upon him insisted that his one chance of life was to get away from his work; so he went to Germany and spent six months at Wiesbaden. Writing so much in his enfeebled condition had weakened and injured his eyes. He was too weak to carry on a long conversation with his assistants, and probably no great project was ever conducted by a man who had to work under so many disadvantages. It could not have been accomplished but for the unselfish devotion of his assistant engineers. Each man had a certain department in charge, and they united with all their energies to have their work properly done according to Colonel Roebling's plans and wishes, and not to carry out any pet theory of their own or for their self-glorification.

When Mr. John A. Roebling met

sudden and painful death in July, 1869, Colonel Roebling was left with three burdens on his shoulders,—the settlement of his father's estate, the care of the manufacturing business in Trenton, and the largest bridge in the world, on which not a stroke of work had been done, the plans of which were most general in character, and not a detail of which had been considered.

The period of time at the end of the sinking of the New York caisson was one of intense anxiety to Colonel Roebling. Below was a bed of sand with an irregular ledge of rock underneath, of a depth varying from 4 to 20 feet. To have gone down to the rock and levelled off the whole foundation would have involved an expense of an additional half million and a sacrifice of another year of time. He, therefore, took the bold step of stopping within a few feet of the bed-rock and leaving an intervening cushion of sand to distribute the pressures. The result, as proved by experience, has been entirely satisfactory.

There is scarcely a feature in the whole work of the bridge that did not present new and untried problems. The methods used to get the material out of the caissons, lighting the caissons, filling them by the supply shaft, and the machinery for raising the stone on the tower all resulted from Colonel Roebling's design.

Colonel Roebling built the anchor plates much larger than his father had intended. Steel cables had never before been used. All previous cables had been made in seven strands, but the cables for the East River Bridge comprised nineteen strands. The use of an elevated foot bridge over the top of the towers was an entirely new feature in this work, as with all previous suspension bridges a foot bridge nearly on the same level as the main bridge had been used. The splice which had formerly been tried for iron wire was not adapted for steel wire, and a new one had to be devised that would retain as nearly as possible the full strength of the wire. This took two years of experimenting before it was satisfactorily accomplished. The manufacture and preparation of steel wire suitable for the cable and the method of handling it caused the Colonel much thought and anxiety.

In personal appearance Colonel Roebling is about 5 feet 10 inches in height. He is a blonde of the German type, with large, expressive gray eyes. While he is unpretentious in manner, his personality is marked by strong individuality and perfect self-composure. He is a man of versatile attainments, being a good classical scholar, a fine linguist, an excellent musician, and a mineralogist with hardly a superior in the country.

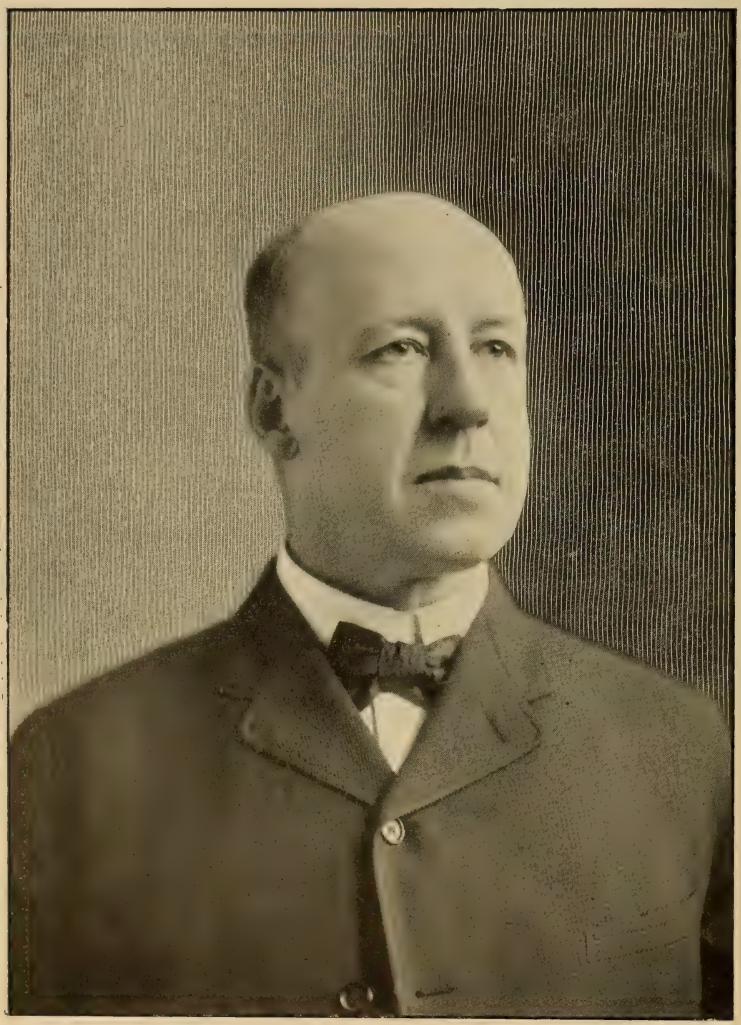


PHOTO BY PATTON, PITTSBURGH

Julian Kennedy

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ELECTRIC RAILWAYS IN BERLIN

THE NEW ELECTRIC UNDERGROUND AND ELEVATED LINES

By Frank H. Mason

AFTER five and a half years of labour in construction, the Berlin elevated and underground electric railway was opened for traffic last February. The new line forms so important an addition to the intramural transit equipment of the German capital and includes in its construction certain features so novel and attractive from a technical standpoint, that some account of the inception and fulfillment of this enterprise may be of interest, as an example of German municipal methods in dealing with transit corporations. Hence, the following particulars, incorporated originally in a United States consular report submitted by the writer. Those familiar with the Berlin of to-

A TUNNEL STATION AT THE POTSDAMER PLATZ

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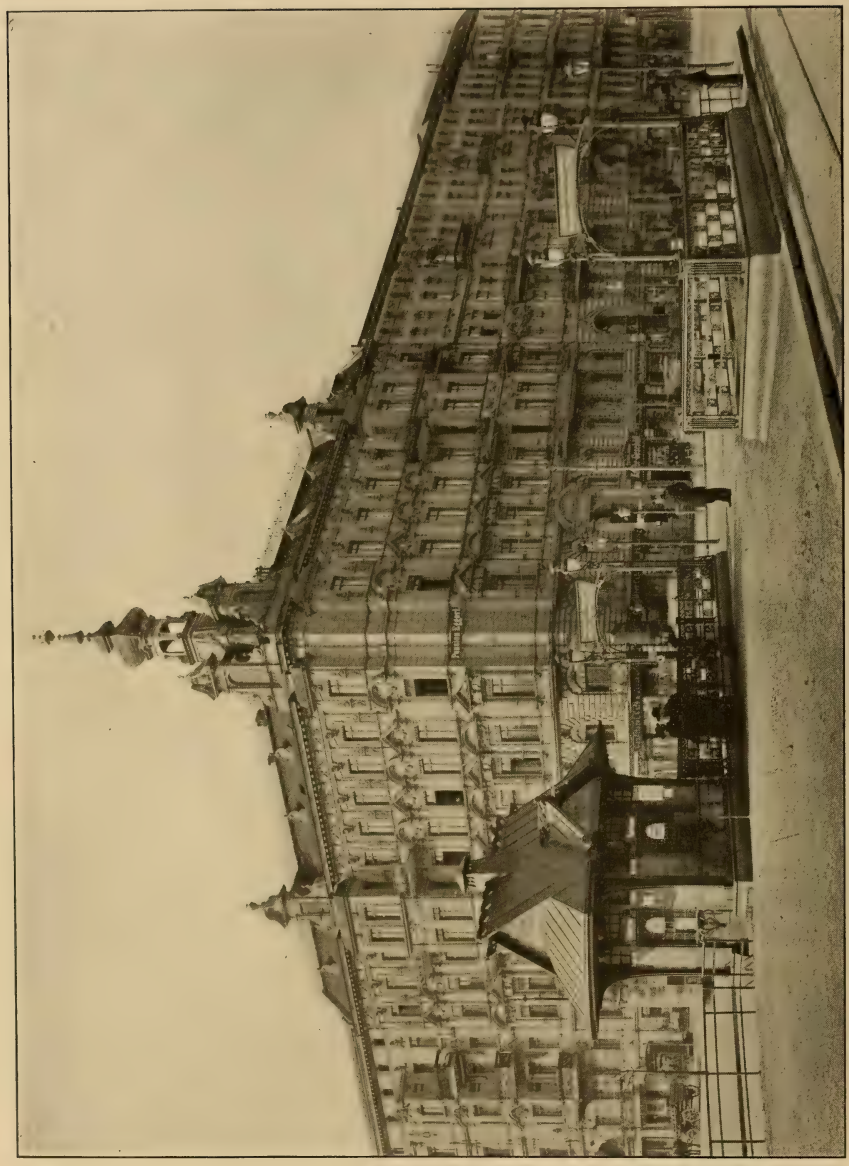


ENTRANCES TO THE TUNNEL STATION AT THE WITTENBERGER PLATZ

ONE OF THE SECOND-CLASS CARS

day know that it possesses, besides a comprehensive and excellent system of electrical surface tramways, an elevated steam railway (Stadtbahn) in two loops, which traverse the city in the form of an elongated figure 8, and a so-called "Ringbahn" or belt line of electrical surface roads on which cars make the circuit at frequent intervals and in opposite directions. But as long ago as 1892, it became apparent that all these were inadequate to handle the steadily growing traffic of the central portion of the city. Many of the principal streets in the older districts are narrow; many which were laid out centuries ago to fit the meanderings of the river are crooked; and at many points where these crowded thoroughfares converge, cars and omnibuses pass so continuously and travel becomes so congested at certain hours that some new means of relief became imperative.

Accordingly, Messrs. Siemens & Halske, the well-known German electrical manufacturers and engineers, petitioned for a franchise to build and operate an electric railway which should be subterranean in the densely-built central portions of the city and elevated in the southern and western precincts, where space and other conditions favoured such construction. The franchise was granted March 22, 1893, for a term of ninety-nine years, and included several rather exacting provisions, which will be hereinafter described. Under it, contracts were made with the munici-

THE TUNNEL APPROACH AT THE NOLLENDORFER PLATZ

pality of Berlin, July 18, 1895, and subsequently with the suburban cities of Schoeneberg and Charlottenburg, through which the projected line was to pass.

Actual work was begun with imposing ceremonies on September 10, 1896. The organisation of the company was completed April 27, 1897, when the Deutsche Bank became the financial backer of the corporation. Its capital is 25,000,000 marks, one-half of which is represented by 4 per cent. bonds, the other half being ordinary stock shares. This company entered into a contract with Messrs. Siemens & Halske, owners of the franchise, by which the corporation acquired all rights and privileges previously granted to the firm. Messrs. Siemens & Halske, on the other hand, agreed to build and equip the road and operate it for one year, with a guaranteed net profit of 4 per cent. on their investment and one-fourth of the net earnings above the guaranteed limit. After the road shall have been thus operated for one year by its builders, it will pass into the permanent control of the company.

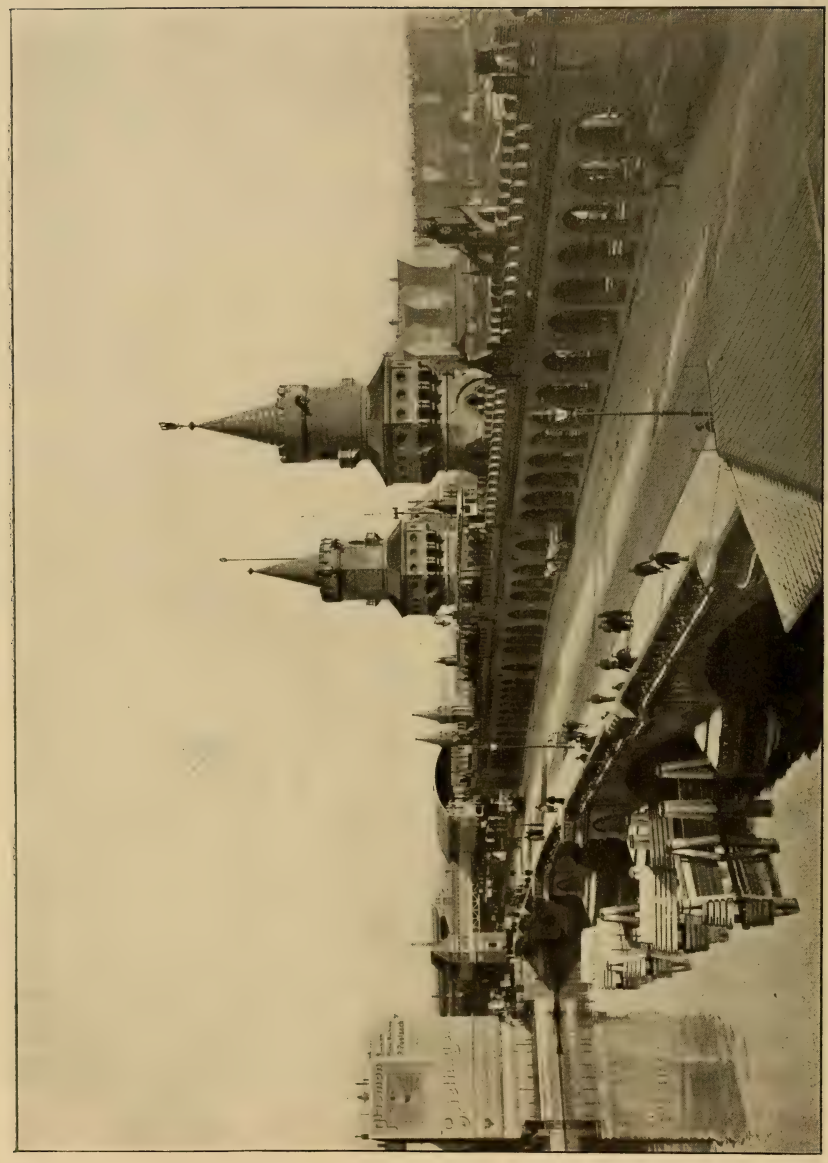
The municipality, in August, 1897, granted right of way for the entire distance, viz., 10.4 kilometers (6.5 miles), of which 7.8 kilometers (4.8 miles) are in Berlin proper, 2 kilometers (1.2 miles) in Schoeneberg, and 1.4 kilometers (0.8 mile) in Charlottenburg,—two populous and handsome suburban cities which adjourn Berlin on the south

and west, respectively. For the use of this right of way, the company is pledged to pay to the municipality of Berlin 2 per cent. of its annual earnings up to 6,000,000 marks. If they reach 7,000,000 marks the percentage will be 2¼ per cent., and so on, one-fourth of 1 per cent. increase for each additional million marks earned. From the beginning of the fifth year after the date of granting the franchise, not less than 20,000 marks shall be paid as such percentage. The municipality of Schoeneberg receives eight thirty-sixths of 1 per cent of the earnings up to 7,000,000 marks, and one thirty-sixth of 1 per cent. for each million earned above that figure.

Thirty years after the road shall have been opened, the three municipalities have a joint option of ten years' duration during which to purchase the entire property at a fair valuation. If they choose to waive this option, the road will be operated by the company until the expiration of its 99-year franchise, when it reverts to the exclusive possession of the municipality.

The wholly underground section of the road which leads from the Potsdamer Platz northeastward to the Alexander Platz beyond the river is still in abeyance, and will not be commenced until the overhead sections have been operated and their efficiency, both technical and commercial, demonstrated by the test of actual experience. These two sections start from a common underground terminus at the Potsdamer Platz, one of the focal points of city traffic where the steam railways from Wannsee, Potsdam, and beyond meet the Ringbahn and several other important electrical tramway lines. From this starting point, the new line runs underground about 200 yards, passing beneath the Potsdam Railway Station; thence mounting by a sharp gradient to a steel overhead construction, it continues southwestward about a quarter of a mile and crosses the Landwehr Canal. At this point, the line is divided

A STATION ON THE ELEVATED LINE AT THE BULOW STRASSE



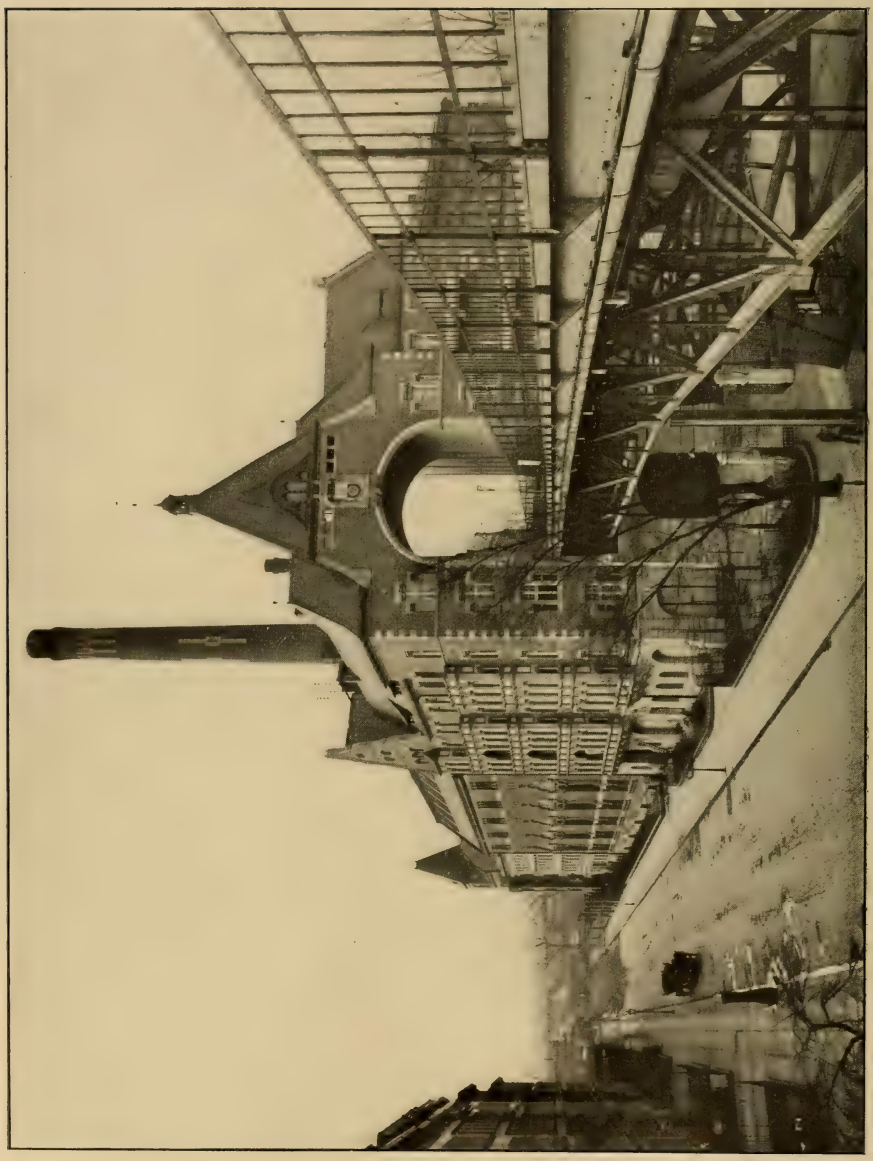
CROSSING THE RIVER SPREE. THE OBERBAUMBRUECKE

by a very ingeniously constructed three-cornered switchback, one side of which curves at a radius of 90 meters (296 feet) and the other at a radius of 263 feet. From this junction one branch, all of elevated construction, extends eastward through a south-central and densely-built industrial and commercial quarter to the Stralauer Gate, crossing the River Spree on a beautifully designed bridge of red brickwork, over which the electric line passes along a handsome arched viaduct about 20 feet above the roadway. This eastern branch is about 3½ miles in length, and has eight stations, two of which are located north of the river. The other branch turns westward from the switchback junction and passes on overhead constructions of steel and masonry through the Dennewitz Platz, follows the Bülow Strasse through a superb station at the Nollendorf Platz, and then, descending a sharp grade, passes through a tunnel nearly a mile in length which underlies Kleist Strasse, Tauenzien Strasse, passes round the Kaiser Wilhelm Memorial Church, and terminates, for the present, at a subterranean station adjacent to the Zoological Garden Depot of the overhead city and long-distance steam railroads. This western branch is being extended 2 miles farther to the Wilhelms Platz, in Charlottenburg. It has at present five stations, two of which—Bülow Strasse and Nollendorf Platz—are overhead, the three others, including the two terminals at the Potsdamer Platz and the Zoological Gardens, being underground. The largest station on the entire system is the eastern terminal at the Warschauer Bridge. It is in the form of a curved viaduct, 300 meters (976 feet) in length by 27 meters (88 feet) in width, with three platforms, each 250 feet long. The line is double tracked throughout, and trains are run in either direction at intervals of five minutes during the busy hours of morning and evening, and at ten-minute intervals during the middle of the day and after 8 o'clock in the evening.

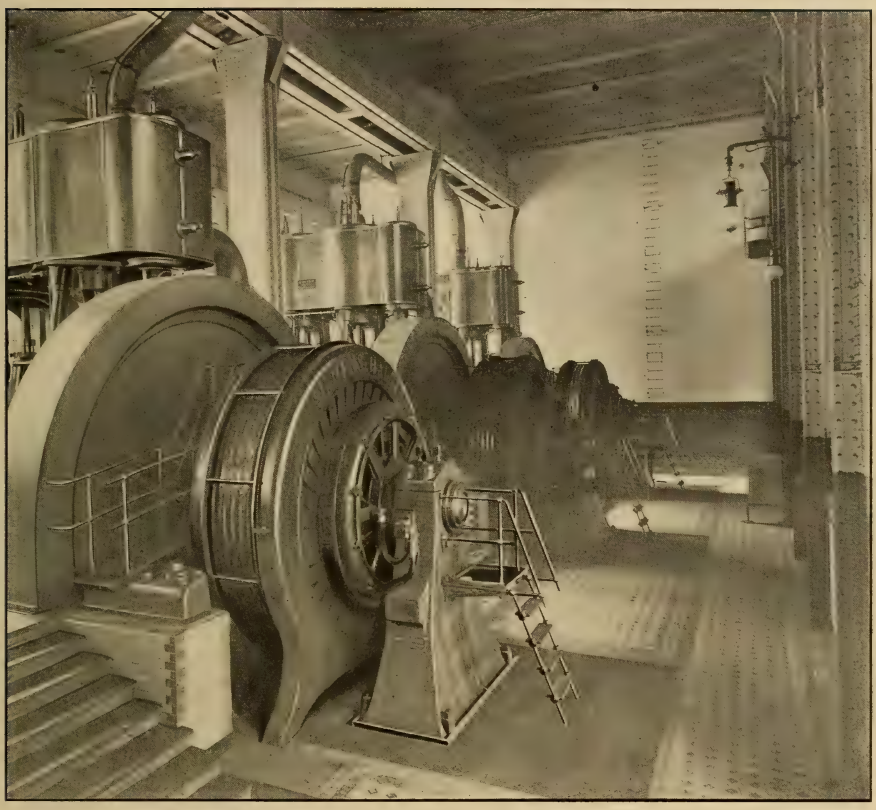
THE POWER SUPPLY AND EQUIPMENT

Power is supplied by a plant located near the switchback junction already mentioned. It includes three direct connected dynamos, each of 800 kilowatt capacity, driven by three steam engines, each having a normal capacity of 900 effective horse-power and a speed of 115 revolutions per minute. The steam supply comes from six boilers of the Gehre type. The furnaces are fed automatically from above with coal brought from canal boats by means of a Hunt conveyor.

The current is conducted to the cars by a third rail laid between the two inner rails of the double track and insulated from the steel superstructure by wooden blocks, interlaid with cushions of felt. The trains are made up of three cars each, viz., a third-class car front and rear and one for second-class passengers in the middle. Both third-class cars are motor vehicles and seat 40 passengers each. The middle car seats 44 passengers, so that, as no standing in aisles or on platforms is allowed, the capacity of a train is limited to 124 passengers. The system of propulsion employed is that of locomotive control and would be probably considered somewhat antiquated in the United States, for example, where the system of multiple units—trains made up wholly of motor cars all under control of one motorman—is now in use on some of the elevated railways. This permits trains to be increased or diminished in length to fit the varying traffic at different hours of the day, and, by making each car self propelling and independent when divided, eliminates the costly element of dead weight hauled empty at hours when it is not needed. It should be remembered, however, that in one respect—that of different classes—the conditions in Germany are quite differnt from those in America, and this consideration was no doubt potent in determining the system of propulsion to be employed. In America, all passengers on the interurban railways are of one class, and each car can be made an independent unit; here, each train must have cars for at least two classes of passengers, and to meet this necessity the trains of the new Berlin line have been made up of three cars, as above described.



THE POWER STATION

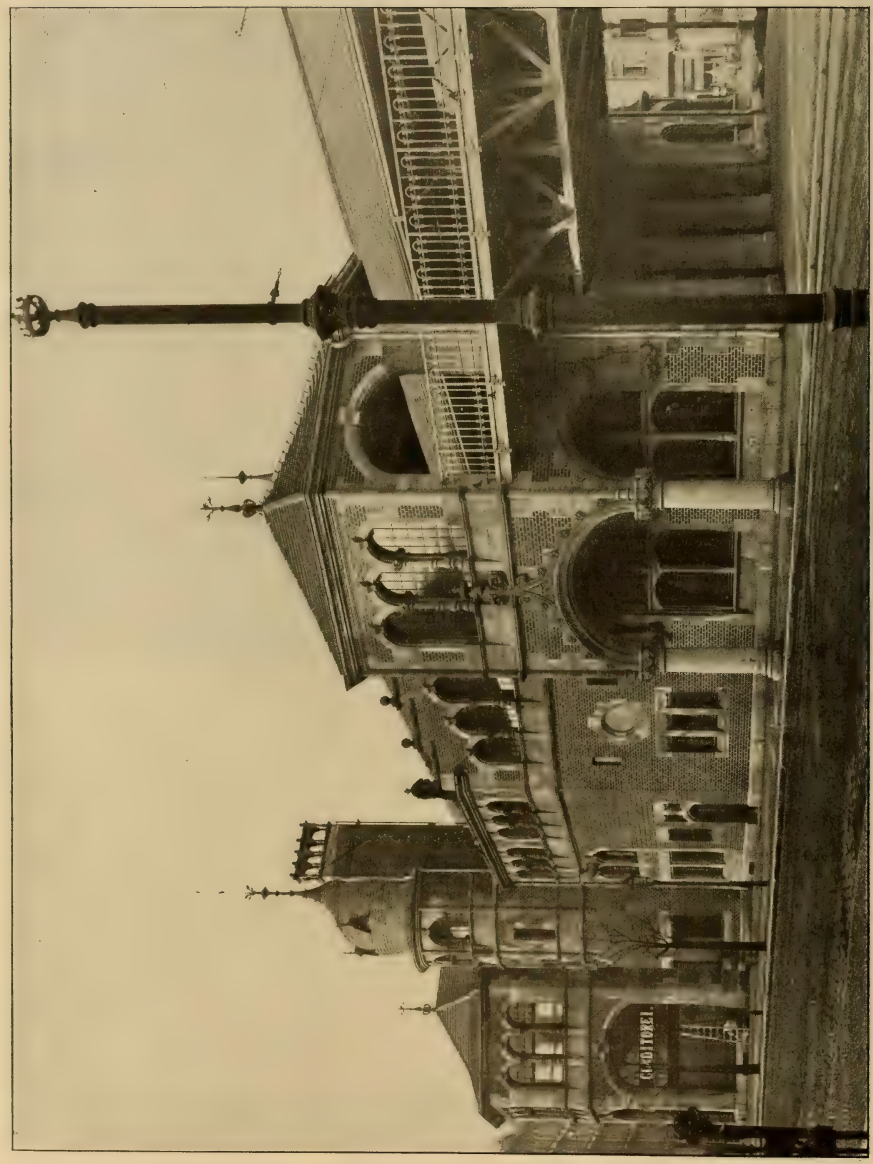


A VIEW OF THE INTERIOR

Each car is provided with air brakes, runs on two four-wheel trucks, and every third-class car carries at one end three electric motors of 71 horse-power each, which operate both axles of the truck. The motors are designed for an average service speed of 30 kilometers (19 miles) per hour, with a practical maximum of 50 kilometers (31 miles), which is the limit of speed permitted on the line.

THE STATIONS AND ELEVATED ROADWAY

In the general plan, equipment, and application of electrical power to the working of this new line, little is presented which can be regarded as novel or especially suggestive. The one respect in which the German constructors leave others far behind and offer an object lesson worth careful study, is in the artistic beauty, the architectural charm and sense of fitness, which they have imparted to the stations, the bridges, and even the ordinary overhead viaduct sections of the new road. Elevated railways in America, for example, are admittedly efficient and well managed; they run spacious, well-ventilated, comfortable cars at high speed for fares which are very low in comparison with carriages and other means of transportation. But they are for the most part plain and commonplace in appearance, and the stations, even in central and populous precincts, are often buildings which are considered blemishes to the neighbourhood. Here, the requirements of public taste are never permitted to be neglected or forgotten. Where the new Berlin line passes through a public square, it is on solid and artistically designed masonry. The



THE STATION AT THE SCHLESISCHES THOR

above-ground stations are of stone, steel, and glass, no two alike, but each specially designed to fit not only the requirements of traffic at that point, but the adjacent buildings as well—the architectural framework in which it is set. Where, for instance, shall we look outside of continental Europe for inter-urban railway stations like those at the Schlesisches Thor shown opposite, and the Nollendorfer Platz, or a bridge like the Oberbaumbrücke, on page 552, on which this new Berlin line crosses the Spree?

The whole management of the enterprise, from start to finish, illustrates the wise, firm control which the municipality of Berlin maintains over corporations which ask for franchises at its hands. As one example among many others of the result of such control, the western branch of the new line from the Nollendorfer Platz to Charlottenburg passes through a series of broad, handsome boulevards in the new and choicest residence portion of the city. There was abundant room for a viaduct along the broad central esplanade between the driveways, and to have built it as such would have saved millions of marks. But the overhead construction, however artistically designed, and the roar and rush of trains would have defaced such a neighbourhood. The company was, therefore, compelled to lower the grade from the Nollendorfer Platz westward, underrun the boulevard and keep out of sight and hearing thenceforward until reaching the ultimate terminus at Charlottenburg. In running this tunnel past the Memorial Church, quicksands were encountered which could be mastered only by extensive and costly piling that involved months of unexpected delay; but the engineers and workmen persevered. That whole section of the line is now finished, the excavated channel is walled, roofed with earth resting on steel girders and arches of masonry, and surfaced with graveled walks, to be planted with shade trees as before the work began.

The convenience and economy of time which will be secured by the new line to dwellers in the eastern and western portions of the city will be important. From the Potsdamer Depot to the Zoological Garden Station, which now requires twenty-one minutes by the surface tramways, will be accomplished by the underground line in about ten minutes. The distance from the Zoological Garden to the extreme eastern terminus of the Warschauer Bridge, which now requires fifty minutes by surface tramway and thirty minutes by the present Stadtbahn (elevated steam railway), will be run by the trains of the new line, with stops at eight intermediate stations, in about twenty minutes.

BRITISH TANK LOCOMOTIVE TYPES

By J. F. Gairns

IN the May number of CASSIER'S MAGAZINE, in an article entitled "The Handy-men of the Railway," the writer considered the tank-engines on British railways according to types. Then, however, he confined himself to the types in common use, and passed over, with brief mention only, the many special types which have been, or are, in use on certain railways. These it is proposed to deal with in the present article.

On the diagrammatic chart on page 560 are shown, first, the standard and ordinary types, as dealt with in the former article, and, second, the special types to which direct attention is now to be directed. For convenience of reference each type has been given a distinguishing letter. The arrows indicate the front of the engine in each case.

Types *A*, *B*, *C*, and *D* represent the old types which are not now standards, though there are hundreds of engines of types *B*, *C*, and *D* still doing good work. Type *D* is still used for shunting and local goods work on several railways, and is the rule for contractors' and dock engines.

Types *E*, *F*, *G*, *H*, and *I* are present standard types. During the forties and fifties raged that intense rivalry between partisans of the broad (7′) and narrow (4′8½″) gauges which did so much for locomotive development and which has been aptly termed "the battle of the gauges." Among the many remarkable engines which this period produced, the truly wonderful broad-gauge 9-foot double-bogie tank engines designed by Mr. Pearson for the Bristol and Exeter Railway, in 1853, must take a prominent place. These unique, yet successful machines, with their huge driving wheels, did splendid work as regards speed, and were able to deal with the best express trains of the time. There are in existence many tales about them as to their speed capabilities, but there is little doubt that they could, and did, reach 80 miles an hour, if not more on occasions.

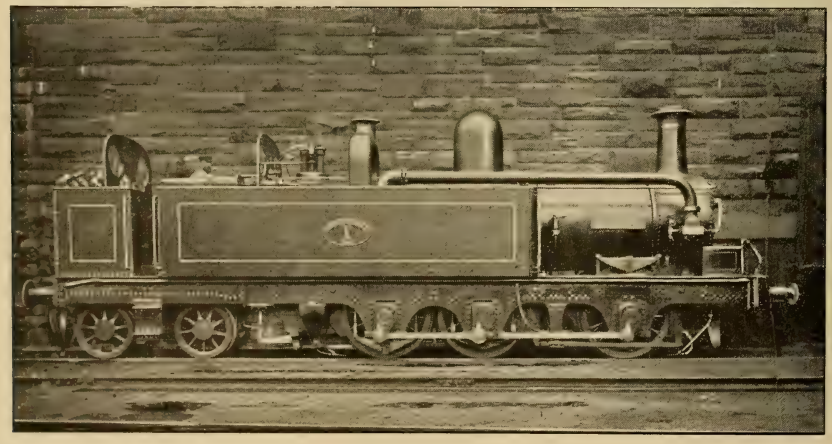


FIG. 1.—A TANK ENGINE OF THE MERSEY RAILWAY
FROM A PHOTOGRAPH BY F. MOORE

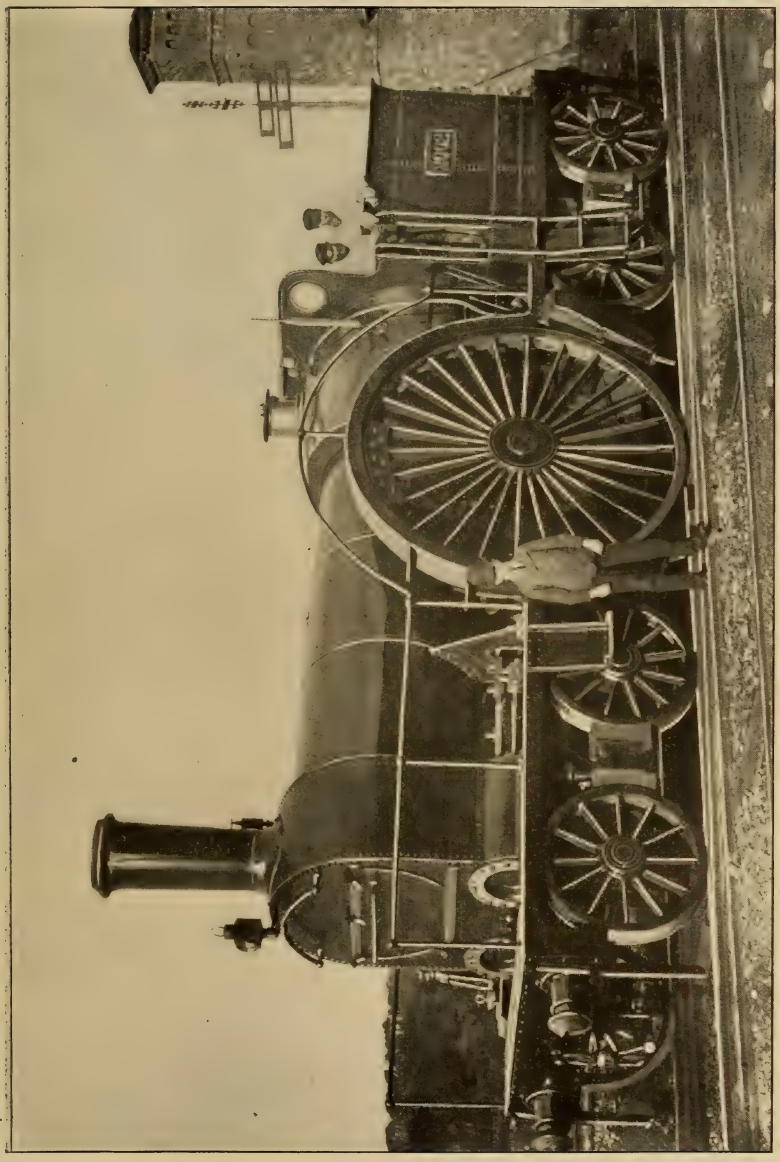


FIG. 2.—ONE OF THE DOUBLE-BOGIE ENGINES WITH 9-FOOT DRIVERS ON THE BRISTOL & EXETER RAILWAY, BUILT IN 1853

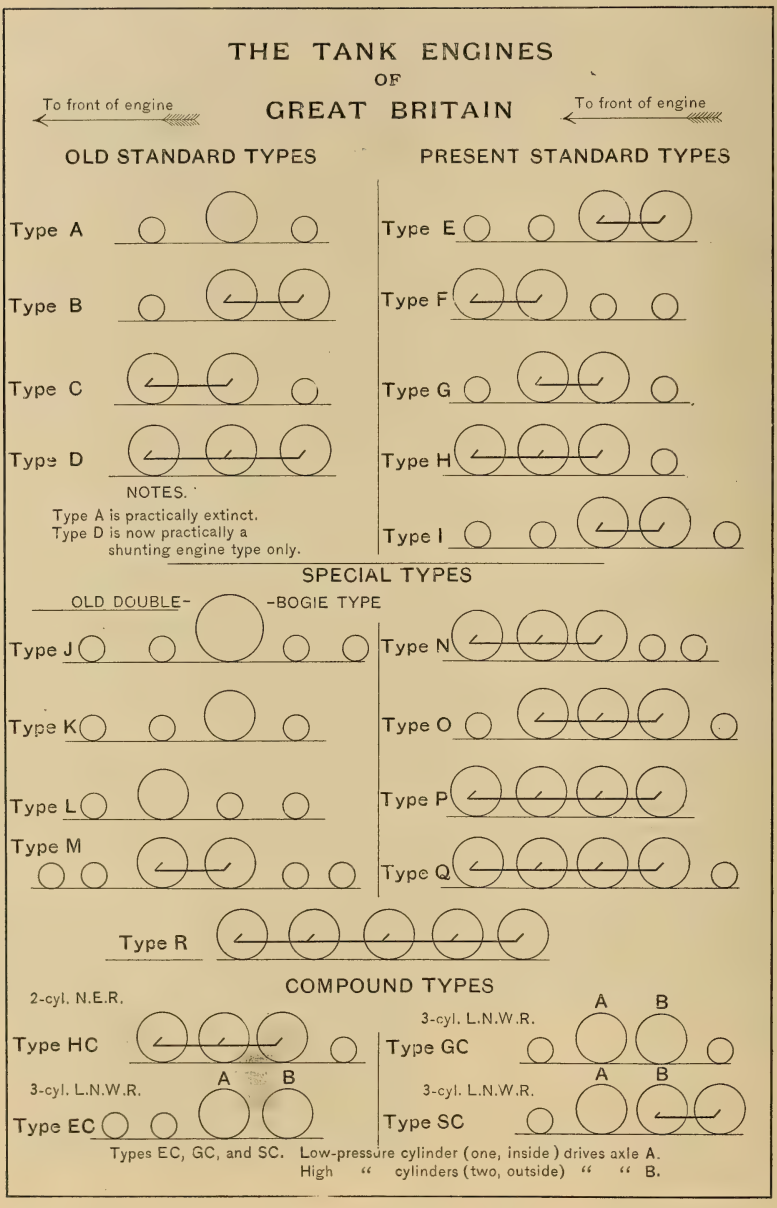

THE TANK ENGINES
OF
GREAT BRITAIN
To front of engine
To front of engine
OLD STANDARD TYPES
PRESENT STANDARD TYPES
Type A
Type B
Type C
Type D
Type E
Type F
Type G
Type H
Type I
NOTES.
Type A is practically extinct.
Type D is now practically a shunting engine type only.
SPECIAL TYPES
OLD DOUBLE-BOGIE TYPE
Type J
Type K
Type L
Type M
Type N
Type O
Type P
Type Q
Type R
COMPOUND TYPES
2-cyl. N.E.R.
Type HC
3-cyl. L.N.W.R.
Type EC
A
B
3-cyl. L.N.W.R.
Type GC
A
B
3-cyl. L.N.W.R.
Type SC
A
B
Types EC, GC, and SC. Low-pressure cylinder (one, inside) drives axle A.
High " cylinders (two, outside) " " B.

FIG. 3.—MR. WORSDELL'S INSPECTION ENGINE ON THE NORTH EASTERN RAILWAY

By the courtesy of Mr. G. J. Churchward, the new locomotive superintendent of the Great Western Railway, the writer is enabled to show one of these engines (type *J* on chart) in Fig. 2. When taken over by the Great Western Railway, these engines were rebuilt as bogie tender engines, and their wheels were replaced by 8-foot wheels. In this state they worked for many years, and, it is said, proved quite as fast with their smaller wheels as in their original condition. The type has gone, but, even by generations who have known them

FIG 4.—MR. HARRISON'S INSPECTION ENGINE ON THE NORTHERN DIVISION OF THE NORTH EASTERN RAILWAY

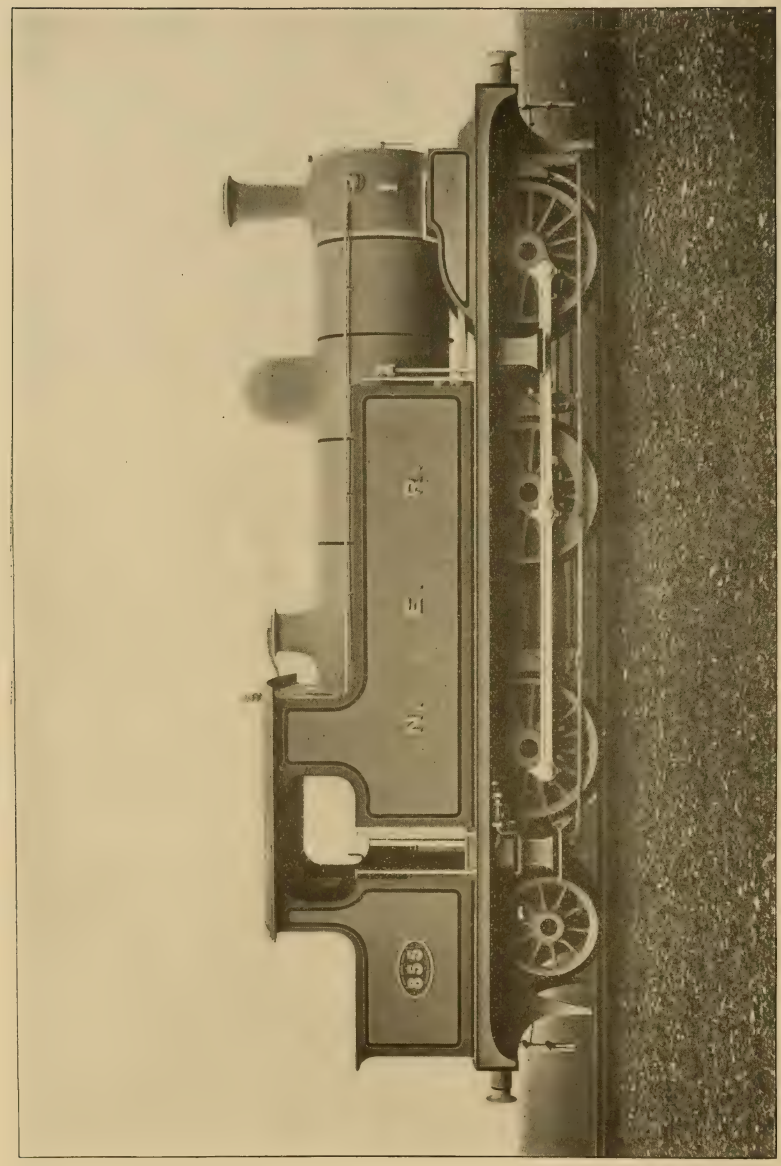


FIG. 5.—A TWO-CYLINDER COMPOUND ENGINE ON THE NORTH EASTERN RAILWAY

not, these tank engines will be remembered, and Mr. Pearson's name will not be forgotten.

A few years ago Mr. Dugald Drummond, locomotive superintendent of the London & South Western Railway, built a combined engine and carriage for inspection purposes, which is strictly of this type (type *J*), the rear bogie being of long wheel base to support the carriage portion. With the exception of this handsome machine, type *J* has become quite extinct.

In the early days on the Great Western Railway and on the allied broad-gauge lines there were a number of saddle tank engines of type *K*. The front four wheels were not in a bogie frame. This type, with the leading wheels in a bogie frame, also applied, until about a year ago, to Mr. Worsdell's private engine No. 66, used for hauling an inspection saloon on the North Eastern Railway. Now, this engine has been rebuilt to type *L* and is similar, as regards type, to the private engine of Mr. C. A. Harrison, engineer for the northern division of the same railway. In Figs. 3 and 4 both these engines are shown as they now are, Mr. Worsdell having kindly supplied the photographs. The driving wheels of No. 66 are 6 feet in diameter, and those of No. 190, 6 feet 6 inches. It is said of these engines that they can be started three minutes ahead of the fastest express on the line, and there will be no risk of the latter being blocked.

Type *M* represents the double-bogie four-coupled engines owned by the Wirral and Midland & South Western Junction Railways. On the former of these railways there is one engine of this type which has given splendid results; so much so, that, the writer is officially informed, two more engines of the type have just been ordered, and these will be fitted with Belpaire fireboxes and sundry other detail improvements. On the Midland & South Western Junction Railway two of these engines are in use, with driving wheels 5 feet 3 inches in diameter. The Wirral Railway is a most "go-a-head" railway as regards tank-engine design, for with a total locomotive stock of thirteen engines, it has, besides the novelty just mentioned, two six-coupled trailing bogie engines of type *N*, of which also there are good reports.

The other railway which uses type *N* is the Mersey Railway, a line which works with the Wirral Railway, many trains being run from one line to the other, engines being changed at Birkenhead Park Station. Fig. 1 shows one of the Mersey engines. The wheels are 4 feet 7 inches in diameter and the cylinders measure 21 × 26 inches. The engines are powerful machines, as they have need to be considering the very steep gradients—much of 1 in 30 and a short piece of 1 in 27—which they have to overcome at the approaches to the Mersey Tunnel. There are nine of these engines, and nine of another six-coupled type which also requires consideration. This is type *O*, six-coupled double-ender engines. These are the more recent engines. The wheels are 4 feet 7 inches in diameter, but the cylinders, outside, are only 19½ × 26 inches.

In 1866 the Great Northern Railway ordered two 8-coupled tank engines (type *P*) for working the heavy goods trains over the Ludgate Hill and King's Cross gradients. At the same time there were a few similar engines at work on Welsh railways. The Great Northern engines have long since been broken up, and, unless any of the Welsh engines still remain, the type is now extinct. Recently, however, type *Q* has appeared on the Barry and one or two other Welsh lines, the engines in the former case being those supplied from America during the much-discussed period of locomotive scarcity in Great Britain a few years back.

Type *R* will probably occasion some surprise. In the United States there are a number of engines of this type in service and there may be some on the continent, but in Great Britain there are at present no ten-coupled engines, either tender or tank. But of the one now being built at the Stratford works of the Great Eastern Railway various descriptions have appeared in the technical

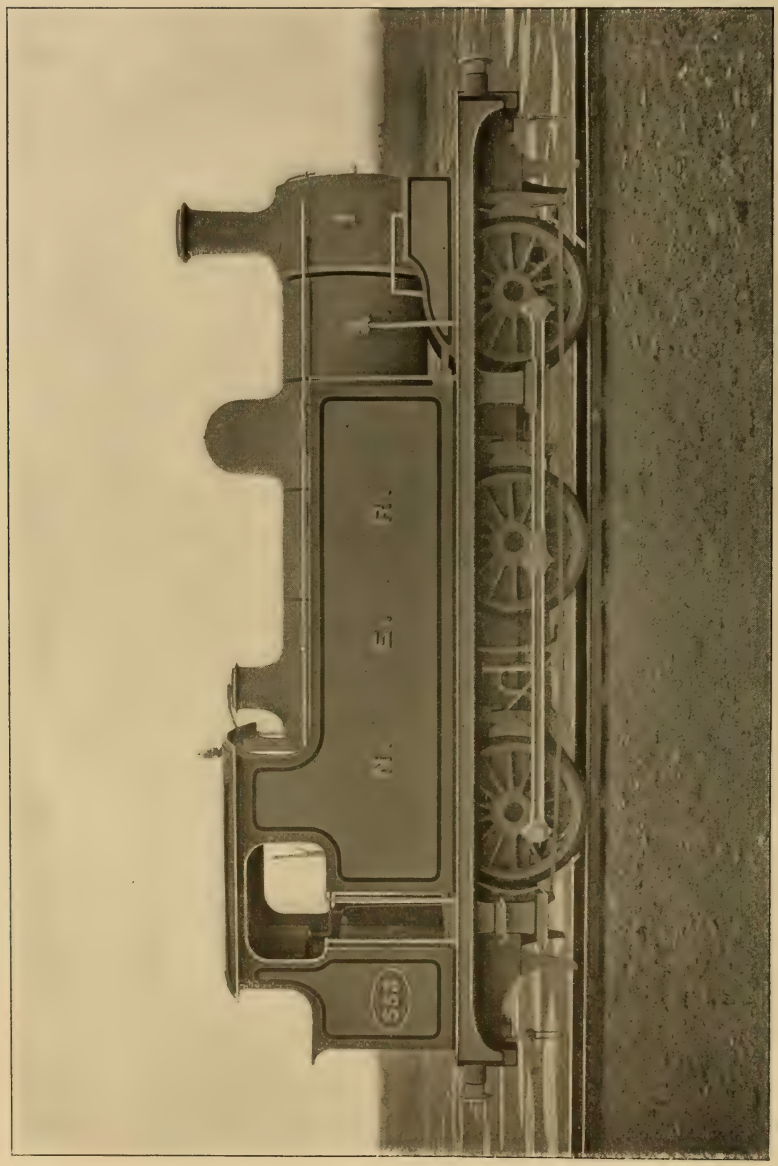


FIG. 7.—STEEP GRADIENT BANKING ENGINE ON THE NORTH EASTERN RAILWAY

press, more or less accurate, and rather premature.

The writer, however, has been informed by Mr. Holden himself that so far as the use of ten-coupled wheels is concerned, the description is correct, and therefore I have included this type on the chart. The appearance of this engine will be eagerly looked for. It will be, no doubt, the greatest novelty in locomotive development of the twentieth century. It seems, however, rather a puzzle, to the lay mind, as to cylinders (outside), driving the rear axle, and one low-pressure cylinder (inside), driving the front axle, the wheels being uncoupled, so that the engines are really "double-singles."

The first engine is represented by type *EC*. Then came two double-end tanks of type *G*, one with 4-foot 6-inch and one with 5-foot 6-inch wheels, and these are represented by type *GC*. Then came the curious six-driver (not six-coupled) engine represented by type *SC*, the only engine, even when six-

FIG. 6.—NEW DOUBLE-END TANK ENGINE ON THE GREAT WESTERN RAILWAY

where the work for such an engine is to be found on the Great Eastern Railway.

Fig. 5 illustrates a North Eastern two-cylinder compound (Worsdell-von-Borries system) tank engine of type *HC* —that is of the standard type *H*, but compounded. On the Belfast & Northern Counties Railway, Ireland, there are now several two-cylinder compound engines of type *I*, and this modified type should be added to the diagram.

The London & North Western Railway is the home of three-cylinder compounds, and some years ago Mr. Webb experimented with several tank engine designs to be compounded on his three-cylinder system,—two high-pressure coupled, with this wheel arrangement ever built in Great Britain, though the type is not unknown on the continent. As will be seen, the high-pressure cylinders drove four-coupled wheels, while the low-pressure cylinder drove only a single pair of wheels, and the engine was, thus, a combined "single" and "four-coupled" engine.

As to their success, they did their work reasonably well, but no new engines were built of the type, and with the breaking up of these engines, three-cylinder compound tank engines have disappeared. As Mr. Webb says, "they were built for experimental purposes to enable me to determine certain data." They served their purpose, and

the matter is closed. Beyond those mentioned, the writer is not aware of any other compound tank engines on British railways.

Before closing the writer would refer to two noteworthy, if not special, classes of engines of standard types as regards wheel arrangement, but which are of great interest. In Fig. 6 is shown one of the new double-ender tank engines (type *G*) just introduced on the Great Western Railway. These engines have the famous "Camel" boilers.

Fig. 7 illustrates one of the special six-coupled tank engines used on the North Eastern Railway for banking goods and coal trains on the Redhenge incline, 1 in 22, from the Teams, on the bank of the Tyne, to Gateshead at the level of the top of the High Level Bridge. These powerful machines are little known, for their work is almost exclusively done on lines not used for passenger trains. They are, therefore, not often seen. They also work in Newcastle, between the Quayside and the Manors, on inclines almost as severe as at Redhenge.

The writer would express his thanks to the locomotive superintendents of most of the railways here mentioned for kindly giving him certain information as to the work, and particulars of their engines, and to Messrs. Churchward and Worsdell for the photographs used to illustrate this article.

ARMOUR-PLATE MAKING IN THE UNITED STATES

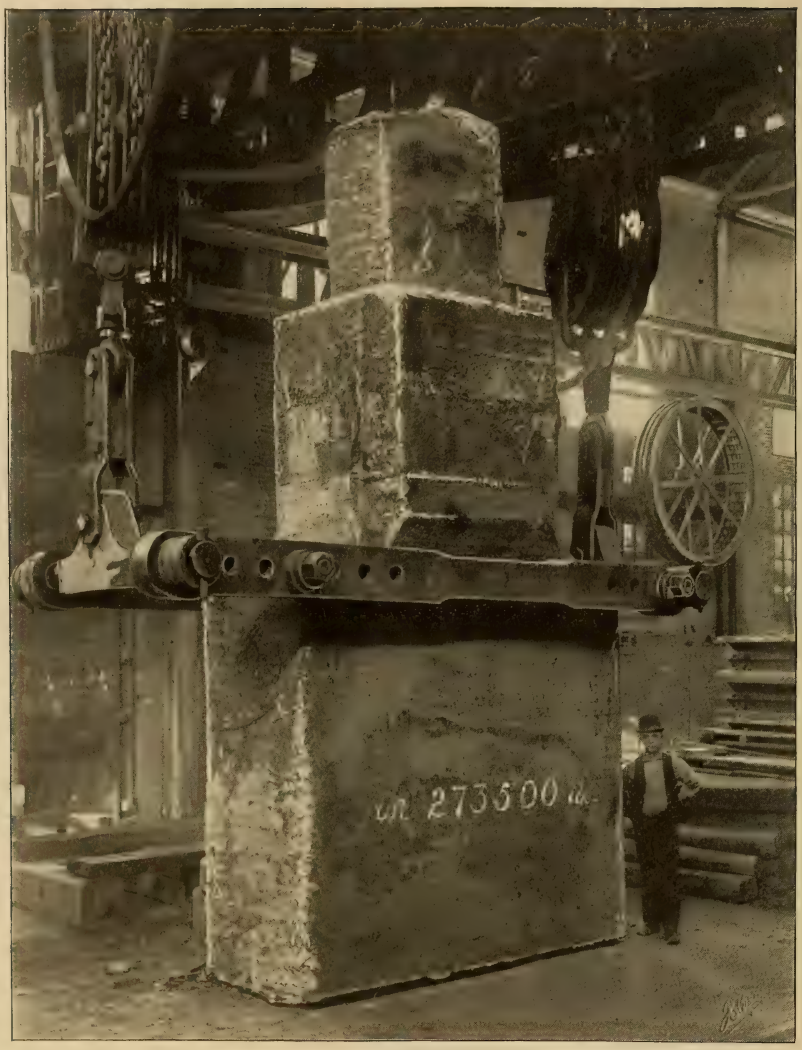
By Rear-Admiral Charles O'Neil, U. S. N., Chief of Bureau of Ordnance

A TRAIN LOAD OF 16-INCH NICKEL STEEL SIDE ARMOUR PLATES LEAVING THE WORKS OF THE BETHLEHEM STEEL COMPANY, SOUTH BETHLEHEM, PA.

THE manufacture of armour plate as an industry in the United States dates back only to the year 1888, as prior to that time, there being no demand for armour, no establishment in the country was equipped with the necessary machinery for making it, or fully understood the process of manufacture; but as soon as a demand was created, private enterprise quickly provided a source of supply. It is difficult at this time to understand the indifference that existed in this country for a period of at least twenty-five years prior to 1888 with regard to armoured ships of war,—a subject which during that time had deeply engrossed the attention of other leading maritime nations of the world, several of which had created powerful fleets of ironclad vessels before the people of the United States had awakened to the necessity of following their example. The enjoyment of peace after the long years of civil war no doubt had much to do with this seeming indifference. During the succeeding years the wooden ships of which the United States Navy was almost entirely composed gradually went to decay, until there was but a vestige of a navy remaining, and when matters got to the worst, in 1883, a reaction set in and the United States Government went to work seriously to build up a modern navy, and found that it was necessary to aid and encourage several new branches of industry which did not exist in the country, but which were necessary in the construction and equipment of modern ships of war.

The United States Navy Register of 1864 contains among the list of vessels of the navy the names of seventy-three "ironclads," showing that the use of armoured protection for vessels of war, even though of an inferior quality, was recognised as an essential feature of their construction at that period, which makes it all the more astonishing that the matter should have been so completely dropped after the close of the Civil War and allowed to slumber for a period of twenty-five years.

The vessels referred to consisted of



A 122 TON NICKEL STEEL INGOT CAST AT THE BETHLEHEM STEEL WORKS FOR ONE OF THE 17 INCH PLATES OF A GUN TURRET OF THE U. S BATTLESHIP "IOWA"

double and single-turreted monitors, of which several remain on the navy list to-day, though the vessels themselves are of but little value, having obsolete guns and very inferior armour. There were also some of the so-called light-draught monitors, which proved to be utter failures, and a number of Mississippi River steamers which had been adapted for military purposes, and a few of more notable type, such as the *Dunderberg*, *New Ironsides*, *Galena*, and *Keokuk*.

The armour of nearly all of the United States vessels of that period consisted of several layers of thin plates, each about 1 inch thick, laid on heavy wooden backing, and while of very inferior quality, as viewed from the present standpoint of efficiency, it proved to be quite effective against the artillery then opposed to it. The old monitors received many hits off Charleston, some of the records being as follows:—*Mon-*

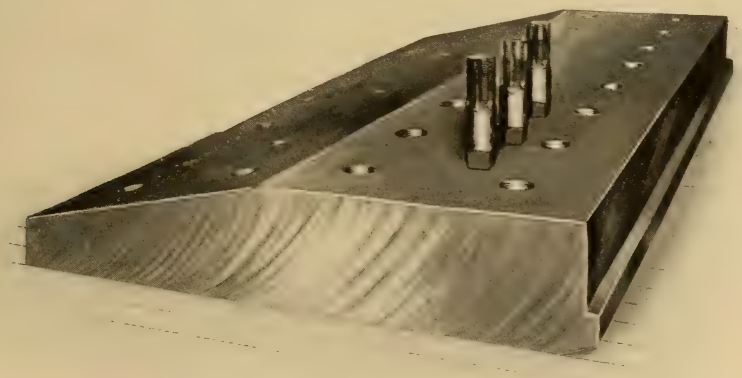
tauk, hit 214 times; *Weehawken*, 187 times; *Patapsco*, 144 times; *Passaic*, 134 times; *Catskill*, 106 times; *Nahant*, 105 times; *Nantucket*, 104 times; *Lehigh*, 36 times; and the *New Ironsides*, 193 times. Many of these hits were from 10-inch guns, and though the vessels were, as a rule, able to remain at their stations, they suffered considerable injury, though but little was said about it at the time.

The most notable United States ironclads of that period were the *Dunderberg* and the *New Ironsides*, and a few words concerning them may not be without interest. The *Dunderberg* (or Thundering Mountain) was built by William H. Webb, at New York, and is described in the official papers as "an iron-clad, shot-proof, steam-screw-ship-of-war with ram, to be built of wood and cased with iron." She was designed to carry two revolving gun-turrets on the casemate deck, each 21 feet in diameter and 8 feet high in the clear, the armour iron of which was to be 11 inches thick. Each turret was to contain two guns of 15-inch caliber, and in the casemate eight 11-inch Dahlgren guns were to be carried. The turrets were to be turned by steam. There was to be a "shot proof pilot-house" on one of the turrets or on the casemate deck. The engines and boilers were to be "of sufficient capacity to propel the vessel at least 15 knots per hour for twelve consecutive hours in fair weather and smooth water at sea." The vessel was to be completed in fifteen months from July 3, 1862. The guns were to be supplied by the government, but the contractors were to furnish the gun-carriages. The contract price was $1,250,000.

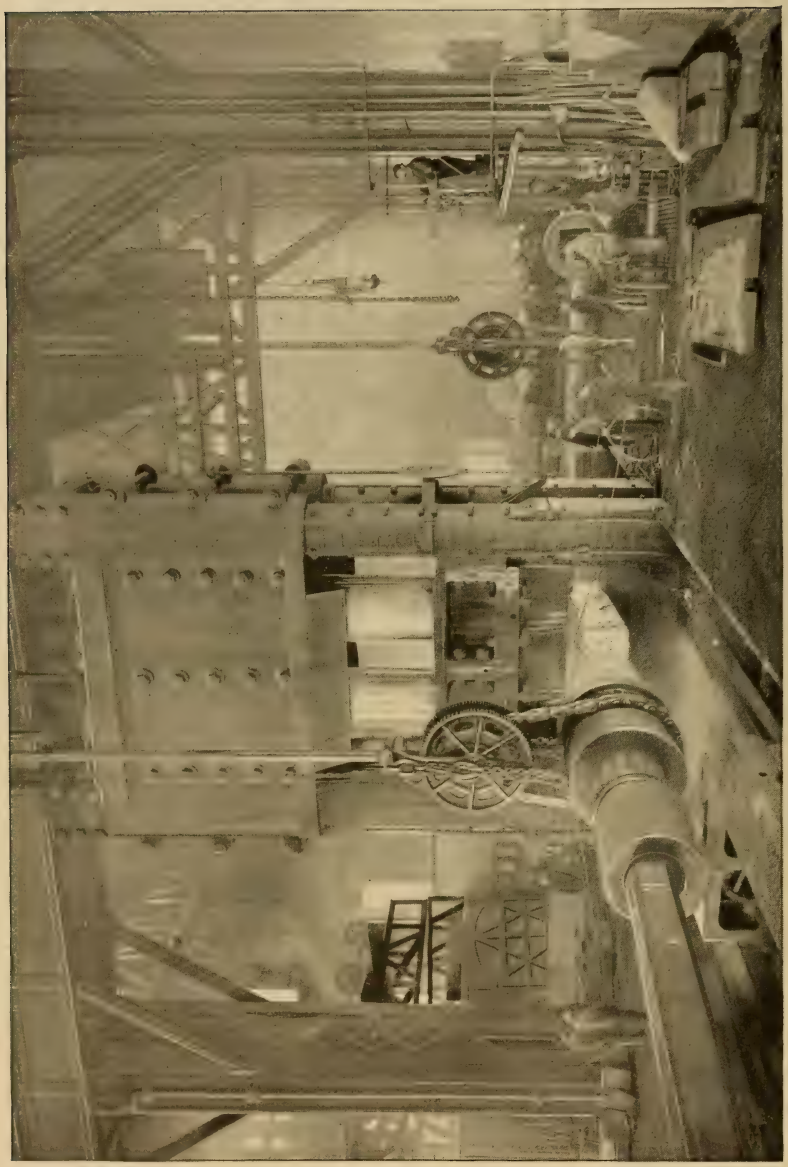
The port-shutters were of wrought iron, 4½ inches thick, and the outer hull was of wood, 6 feet thick at the main deck level, decreasing to 2 feet at the bilge. The under-water body was coppered. The sides of the vessel from the main deck to about 5 feet below the load-water line were covered with iron 3½ inches thick from deck to water line, tapering to 2½ inches at the lower edge, and also tapering towards the bow and stern to 2½ inches, made in slabs placed vertically. The sloping sides and ends of the casemate were covered with iron plates 4½ inches thick, made in one thickness, and about 28 inches wide.

The ship itself was a little over 380 feet long and of 73 feet beam, with a displacement of 7000 tons. The total weight of armour was 1000 tons. The engines were of about 5000 indicated horse-power.

The armament as projected was probably more than the ship could carry, and it was finally decided to omit the



AN 18-INCH SIDE ARMOUR PLATE OF THE U. S. BATTLESHIP "OREGON", MADE BY THE CARNEGIE STEEL CO., LTD.



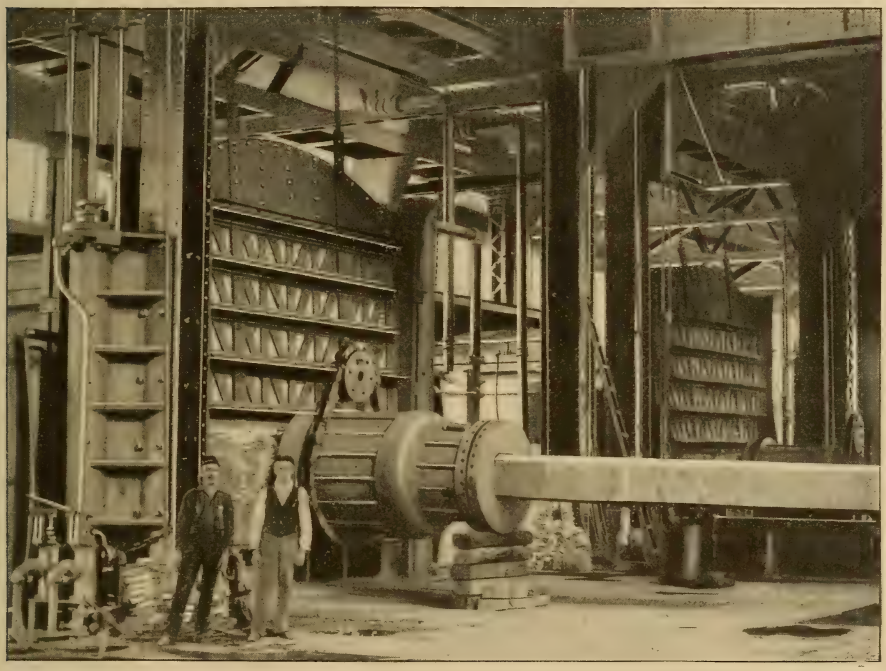
FORGING AN ARMOUR PLATE AT THE BETHLEHEM STEEL COMPANY'S WORKS, UNDER A 14,000-TON HYDRAULIC PRESS. THE PORTER BAR AND CHUCK HOLDING THE PLATE FOR FORGING WEIGH 125,000 LBS., EXCLUSIVE OF THE COUNTERWEIGHTS USED

turrets and the turret guns, and to give the vessel two 15-inch and four 11-inch guns, one 15-inch and one 11 inch gun to be mounted on each broadside and one 11-inch at each end of the casemate. This battery was mounted about February, 1867, from which it will appear that instead of being completed in October, 1863, as required by the contract, the vessel was not completed until three years and a half later.

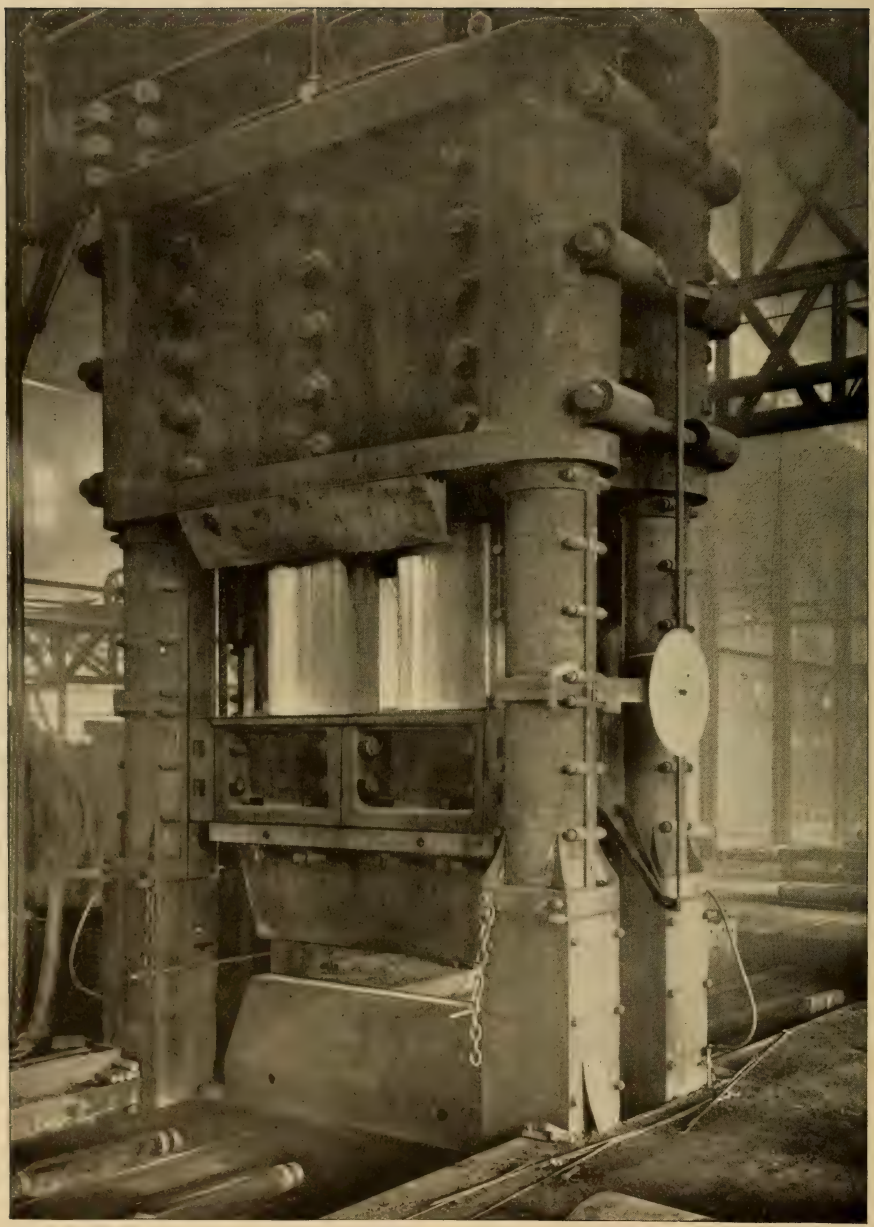
On February 22, 1867, the *Dunderberg* went to sea to test her battery, and its general performance was reported as satisfactory. On account of the omission of the turrets a deduction of $22,860 was made from the contract price. It does not appear that a regular speed trial was made, but it is recorded that at one time a speed of ten knots was attained.

After the vessel was completed, she was, by authority of Congress, turned over to the builders upon payment by them of all moneys paid or advanced by the Government, and Mr. Webb then sold the ship to the French Government. After some alterations, she was put in the service of the French Navy, under the name of *Rochambeau*. There are no records available showing the nature of these alterations or her later history.

The *New Ironsides* was designed and built by the Cramp Shipbuilding Company, of Philadelphia, but the scheme of the vessel was due to Mr. B. H. Bartol, of the Philadelphia engine-building firm of Merrick & Co. She was called a casemated ironclad frigate, with unarmoured ends, except that her waterline was protected by a complete belt. Her battery consisted of fourteen 11-inch smooth-bores and two 8-inch rifles, mounted in a casemate. Her steam speed was about six knots, but she had a good spread of sail in addition Her armour consisted of 4½-inch solid iron plates, backed by 21 inches of oak, the inclination of the casemate being 30



HEATING AN ARMOUR-PLATE INGOT PREPARATORY TO FORGING AT THE HOMESTEAD STEEL WORKS OF THE CARNEGIE STEEL CO., LTD.



THE 14,000-TON HYDRAULIC FORGING PRESS AT THE BETHLEHEM WORKS

degrees from the perpendicular. The armour plates were made at Pittsburgh.

For two years this ship was subjected to the most severe test a war vessel can undergo,—alternate blockade duty and close action against fortifications during the American Civil War. On one occasion she remained in action three hours, alone, against the combined forts of Charleston Harbour, holding down the artillery fire of the batteries until she was obliged to haul out for lack of ammunition. During this time she was struck on her side armour sixty times, but an investigation showed her to be entirely uninjured. In a period of about six months the *New Ironsides* was struck 193 times, and was never forced to leave the station for repairs. After the Civil War the vessel was laid up at League Island, Philadelphia, and was destroyed by an accidental fire.

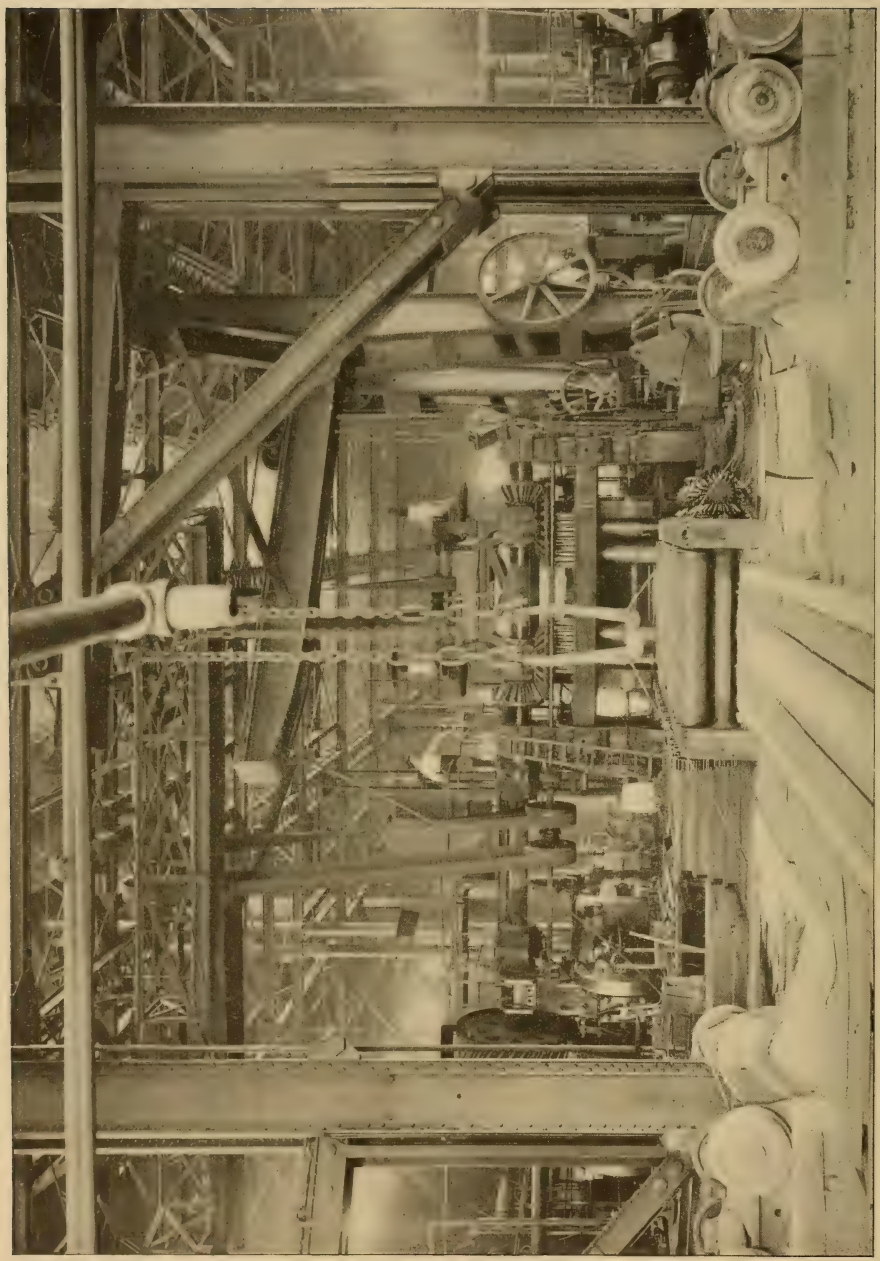
The Confederate American ironclad steamers *Merrimac*, *Atlanta*, and *Tennessee* are well worthy of mention, for when we consider the limited means at hand and the lack of skilled labour available, the results achieved cannot but excite the admiration of naval people. As is well known, the *Merrimac*, or *Virginia*, as she was officially known, was the United States frigate *Merrimac*, which fell into the hands of the Confederacy at the Norfolk Navy Yard when it was abandoned by the United States forces. She was cut down, and a heavy casemate of timber was built upon her. This was covered with two layers of narrow bars of rolled iron, each 1½ inches thick, making a total of 3 inches. These slabs were rolled from railroad iron, and were, therefore, of excellent material. This iron plating was laid over 20 inches of oak, and was placed at an angle of about 30 degrees from the horizontal. So far as known, no material damage was done to the armour of the *Merrimac* by the fire of any of the vessels in action with her, among them the historic *Monitor*.

The Confederate steamer *Atlanta* was built by converting an iron-hulled, blockade-running steamer. Additional displacement was given her by sponsoning her out with square logs, thus increasing her beam, and she was fitted with a central casemate, or citadel, built of 15 inches of Georgia pine, covered by 3 inches of oak, on which were laid two courses of 2 inch iron bars, 7 inches wide (probably rolled from railroad iron), the inner layer being horizontal and the outer one vertical, the fastenings being 1¼-inch through-bolts set up with nuts and washers. She had a battery of two 6-inch and two 7-inch rifles. The sides of the casemates were inclined at an angle of about 30 degrees from the horizontal.

The *Atlanta*, under the command of Captain William A. Webb, of the Confederate Navy, was captured by the United States monitor *Weehawken*, Captain John Rodgers, on July 17, 1863, in the sounds of North Carolina. The *Weehawken* fired five shots, three of which took effect, penetrating the *Atlanta's* armour and killing or wounding many of the crew of two guns. She grounded and surrendered.

The Confederate ship *Tennessee* was after the same type as the *Atlanta*, but was built of wood and specially constructed for use as a vessel of war, and was, therefore, somewhat heavier. The framing of the casemate consisted of an inside diagonal ceiling of 2½-inch oak; vertical pine timbers 13 inches thick; an outside layer of 4 inches of oak timber covered by three thicknesses of 2-inch iron bars, 7 inches wide, the whole fastened by 1½-inch through-bolts set up with nuts on the inside. The armour of the ends of the casemate was 1 inch less in thickness. At the battle of Mobile Bay a 15-inch shot from one of the monitors smashed in the port side of the *Tennessee's* casemate, though the shot itself did not get through. She was struck many times and suffered much injury.

From the vessels above described to the steel-clad floating fortresses of today was a gigantic stride, though the time required for its accomplishment was by no means great. The first of the armoured vessels of the modern United States Navy were the ill-fated *Maine* and the *Texas*, authorised by the Act of March 3, 1886, which Act

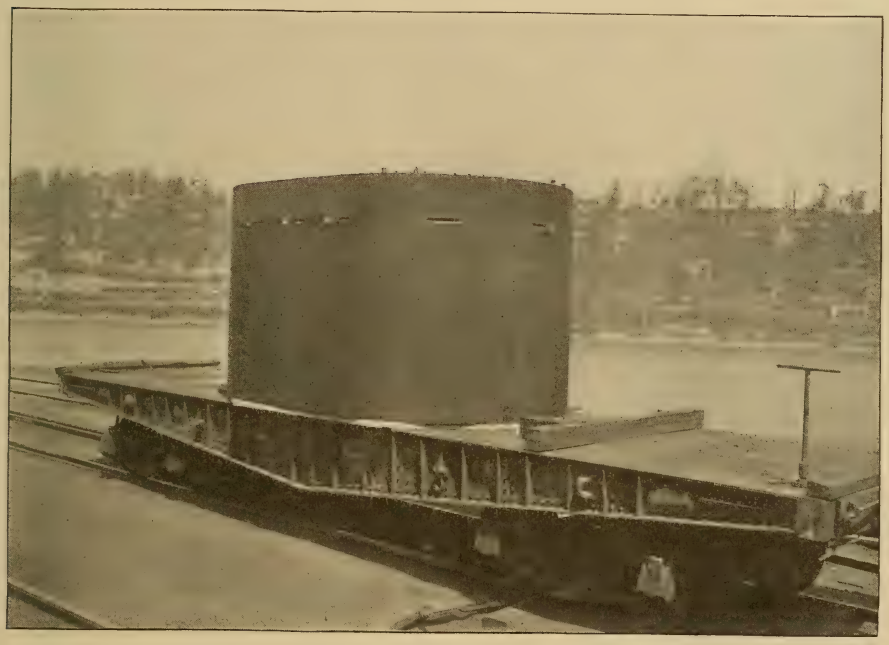


THE ARMOUR-PLATE ROLLING MILL AT THE HOMESTEAD WORKS OF THE CARNEGIE STEEL CO., LTD.

also provided for the reconstruction of the monitors *Puritan*, *Monadnock*, *Amphitrite*, and *Terror*. This authorisation was followed by the issue of a circular by the United States Navy Department, dated August 21, 1886, inviting bids for armour plate and gun-steel of domestic manufacture; and the consideration of the manufacture of modern armour in the United States may be said to date from the issue of this circular.

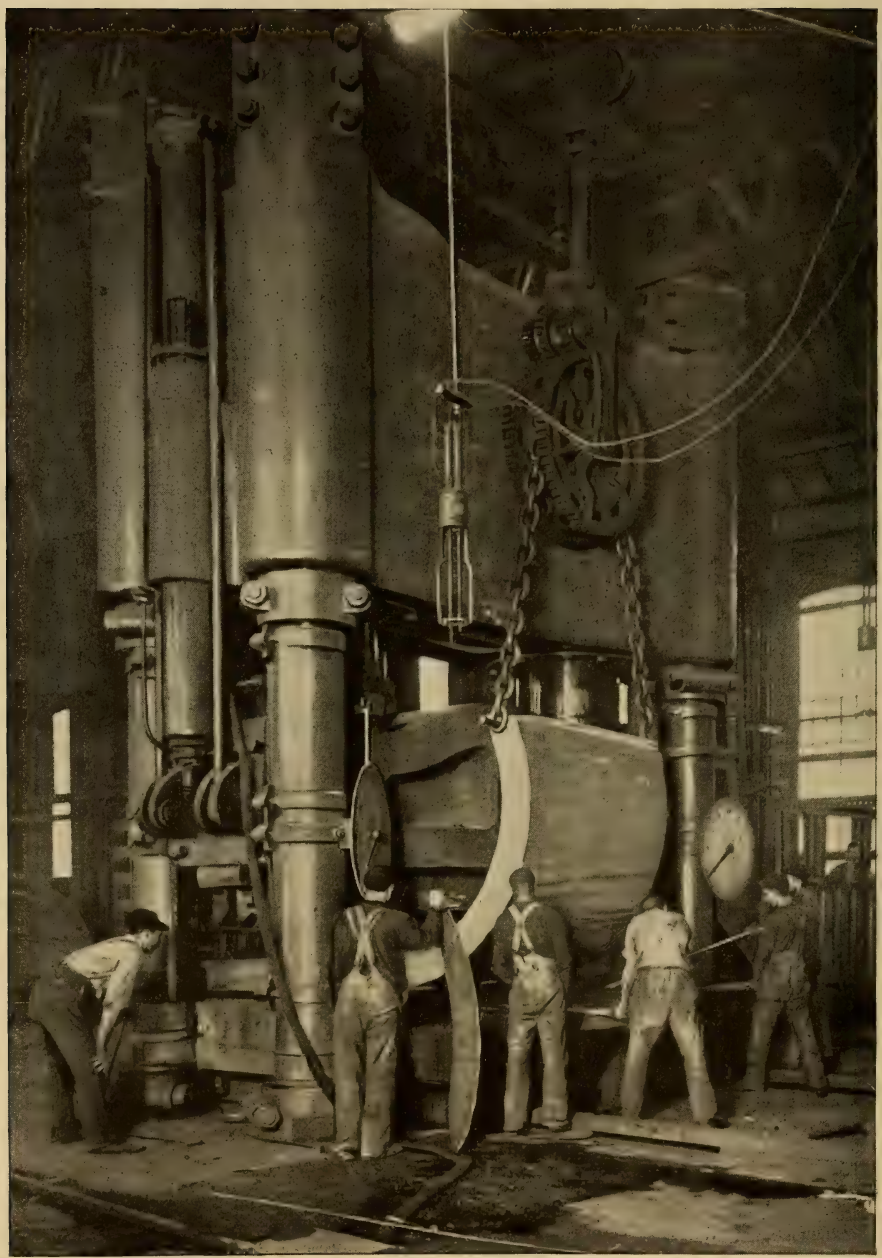
The bids received under this advertisement were opened on March 22, 1887, proposals being received from what is now the Bethlehem Steel Company, of South Bethlehem, Pa., for both; from the Cambria Iron Company, of Johnstown, Pa., and from the Midvale Steel Company, of Philadelphia, for gun-steel only; and from the Cambria Rolling Mill Company, of Johnstown, Pa., for armour plates only. The bid of the Bethlehem Company being the only one for both kinds of material, and being, in the aggregate, the lowest, was accepted, and a contract was made with that company on June 1, 1887, for both armour and gun-steel. This contract included armour for the second-class battleships *Maine* and *Texas*, and for the monitors *Puritan*, *Monadnock*, *Amphitrite*, and *Terror*.

The amount of armour contracted for was estimated at about 6700 tons, and was to be of plain steel, oil-tempered, and annealed; but prior to the first deliveries, which were made in the fall of 1891, radical changes were made in the specifications, and the introduction of nickel and the use of the reforging and face-hardening processes were included.



CONNING TOWER FOR THE U. S. BATTLESHIP "WISCONSIN." OUTSIDE DIAMETERS, 12 FEET 8 INCHES AND 8 FEET 8 INCHES. HEIGHT, 7 FEET. MADE BY THE CARNEGIE STEEL CO., LTD., PITTSBURGH

About the year 1888 a sufficient quantity of armour was ordered from Great Britain for the monitor *Miantonomoh*, this being of the type known as "compound armour," its cost being $535 per ton. Prior to the date of the circular above referred to numerous experiments had been made in Great Britain, Russia, Italy, France, and Germany with various types of armour, and



A 7000-TON PRESS AT SOUTH BETHLEHEM, BENDING AN 8-INCH NICKEL-STEEL PLATE FOR THE TURRET ARMOUR OF THE U. S. BATTLESHIP "MAINE"

from 1882 to 1887 the contest for superiority lay between the compound and the all-steel plates, British manufacturers presenting the former, while Messrs. Schneider & Co., of France, were the chief advocates of the latter.

Compound armour generally resisted penetration better than the all-steel plate, because it was possible to make the thin steel face of the former much harder than that of the all-steel plate, without sacrificing the toughness necessary to prevent breaking up. The chief failure of the compound plate was in the flaking-off of the steel face from its iron back. This led to a continued effort to produce all-steel plates that would present a hard face and still retain sufficient toughness. By the introduction, in 1889, of a small percentage of nickel in the manufacture of steel, unusual toughness was produced.

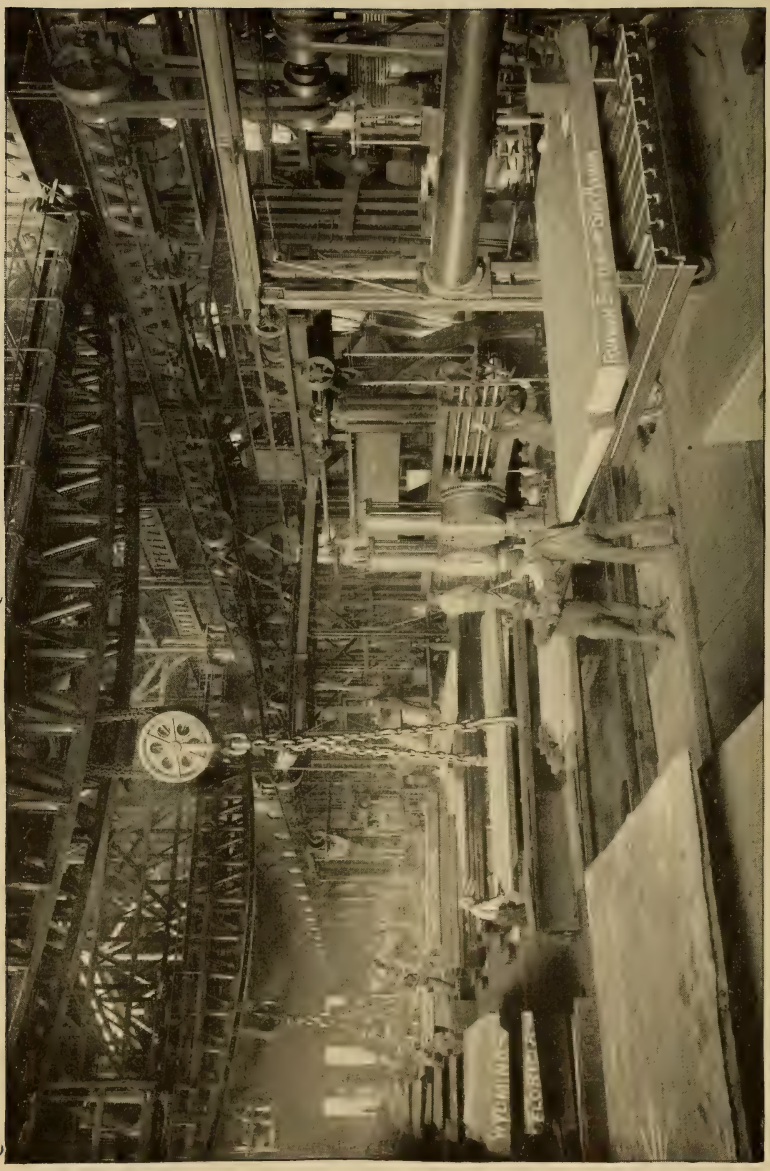
Such was the armour situation when the United States Government commenced the building of armoured vessels for its new navy, and while, as previously stated, the armour ordered for the first of the new vessels was of plain steel, it gave place to that containing nickel as the result of the first important armour test made in the United States at the Annapolis proving ground, in September, 1890. This test was made principally to determine the respective values of plain steel, of nickel-steel, and of compound armour plates.

To carry out this experiment three plates of equal dimensions were procured, namely, 8 feet by 6 feet by 10½ inches, and were subjected to similar attacks. The plates tested consisted of a compound plate made by Messrs. Cammel & Co., Ltd., of Sheffield, England; a plain-steel plate made by Messrs. Schneider & Co., of Le Creusot, France, and a nickel-steel plate also made by the latter firm. All three plates were subjected to five impacts, four by a 100-pound armour-piercing projectile fired from a 6-inch gun, with a striking velocity of 2075 foot-seconds, one shot being directed at each corner of the plates; and a fifth impact by a 210-pound projectile, fired from an 8-inch gun, with a striking velocity of 1890 foot-seconds, at the centre of the plates. All three plates were supported by 36 inches of oak backing. The compound plate was perforated by all the projectiles, and was practically destroyed by the 6-inch alone. The plain-steel plate kept out all the projectiles, but was badly cracked by the 8-inch shot. The nickel-steel plate kept out all the projectiles, and remained without cracks. After these tests it was decided to use nickel-steel for the armour of United States vessels, and the Navy Department took immediate steps to procure a large supply of nickel-matte for such purpose.

Probably no step in the development of modern armour is more interesting or was of greater importance than was the introduction of the Harvey process of face-hardening, originated by the late Hayward Augustus Harvey. At the time Harvey conceived the idea of face-hardening steel plates, in 1889, he was president of the Harvey Steel Company, of Newark, N. J. During that year he treated a block of steel with a view to giving it a very hard face and great power of resistance, and was so successful that he brought his experiments to the attention of the Navy Department, which, at his request, furnished him a small plate 6 inches thick, which was treated at the company's works in Newark, was face-hardened at the Washington Navy Yard under Mr. Harvey's directions, and was tested at the naval proving ground at Annapolis in 1890.

This plate was made by the Linden Steel Company, of Pittsburgh. It was cut in halves, and one-half was treated by the Harvey process while the other half was left untreated. When tested, the treated part showed such superior qualities of resistance over the untreated one that the Navy Department decided to experiment on a larger scale, and, therefore, procured from Messrs. Schneider & Co., of Le Creusot, France, a steel plate 10½ inches in thickness, there being at that time no facilities in the United States for the manufacture of such plates.

This plate was treated at the Wash-



THE ARMOUR-PLATE MACHINE SHOP AT THE BETHLEHEM WORKS

ington Navy Yard in January, 1891, in a furnace especially erected for the purpose, under the direction of Mr. Harvey. The bed of the furnace being first covered with sand a few inches thick, the plate was laid on it in a horizontal position, and its upper face, which was to be treated, was covered with a layer of carburising material, probably a mixture of animal and vegetable charcoal, about a foot thick, over which was laid a covering of tiles to exclude the flame and air from the plate. The doors of the furnace were bricked up, the fires were started, and a high degree of heat was maintained for about one hundred hours.

Much difficulty was experienced in getting the heated plate out of the furnace, and a period of five hours was consumed for this purpose, as the arrangements were very crude. When the plate was finally free from the furnace and was hauled under the sprinkling trough, it was of a dull cherry-red colour, and in this condition it was heavily sprayed on one side with jets of cold water, which fell several feet from the trough above. The cooled surface naturally contracted and distorted the place, which curled up like a saucer. The spraying was continued until the plate was cooled to a black heat, when it recovered its shape somewhat, but the warping was then regarded as a serious objection to the process. In later plates, however, this was overcome by spraying the heated plates on both sides, and in the regular furnaces thereafter constructed the plates were laid on iron cars and could thus be readily removed. The writer of this article was at that time in charge of the Naval Gun Factory, and thus had charge of this interesting experiment which was to cause so great a revolution in the character of the armoured protection of ships of war of all nations.

This imperfectly treated plate was tested at the Indian Head proving ground in February, 1891, being attacked by seven 6-inch projectiles of 100 pounds weight, having a striking velocity of 2065 foot-seconds. The greatest penetration was four inches, except in one round, that at the centre of the plate, when the point of the shell reached the backing. All the projectiles were broken up. The plate was cracked, but until the last round no part of it was detached from the backing. At this round about one-eighth of the plate fell to the ground. These results were considered remarkable, and it was concluded that, by means of this method of treatment, armour of ideal quality, that is, having a very hard face combined with a tough back, without any weld or other line of demarcation between them, could be made.

The Navy Department, therefore, decided to hold a further series of armour trials in which the relative merits of plain and nickel-steel of domestic manufacture, when treated by the Harvey process, should be submitted to exhaustive competition. Accordingly, eight plates, each 6 feet by 8 feet by 10½ inches, were ordered, five from the Carnegie Company and three from the Bethlehem Company. The tests of these plates took place at Indian Head, Maryland, on October 31 and November 14, 1891, but only six plates were fired at, as two of those furnished by the Carnegie Company were withdrawn on account of defects in manufacture.

Each plate received four impacts from 6-inch shell, one at each corner, and one 8-inch shell in the centre. The 6-inch shell weighed 100 pounds, and were fired to give a striking velocity of 2075 foot-seconds. The 8-inch shell weighed 210 and 250 pounds, respectively, and were fired to give striking velocities of 1850 and 1700 foot-seconds, the energy being the same in either case. The three Bethlehem plates used were, respectively, a high-carbon nickel-steel, a medium-carbon nickel-steel, Harveyised, and a plain-steel, Harveyised. The three Carnegie plates were, respectively, a high-carbon nickel-steel, a low-carbon nickel-steel, and a low-carbon nickel-steel, Harveyised.

All the plates showed greater resistance to penetration and less cracking than did the British compound-plate of the previous year. Two of the plates showed greater resistance to perforation

and less cracking than did the most resisting plate at the Annapolis test of the previous year.

The results given by the nickel-steel plate treated by the Harvey process, manufactured by the Bethlehem Company, were considered the most satisfactory, and the conclusion was reached that two important results had been achieved:—First, a better plate of American manufacture had been produced than the Navy Department was able to purchase abroad the year previous; second, the development of a new principle in the manufacture of armour, of American origin, which, there were good grounds for believing, would furnish greater protection to the vital parts of a vessel of war than any other system hitherto employed.

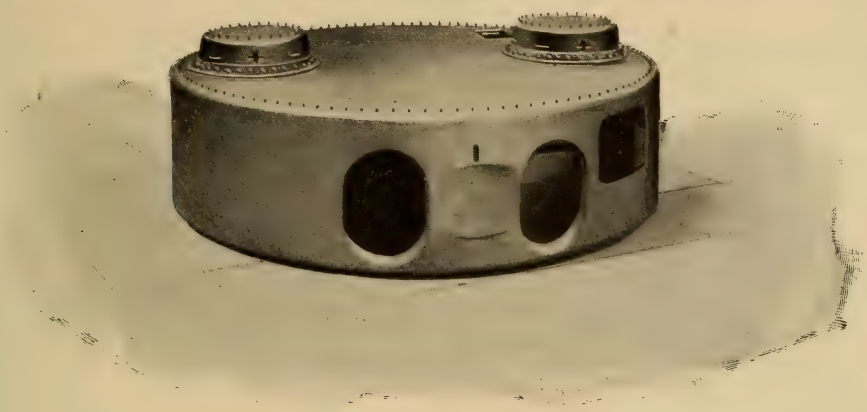
While the foregoing tests were considered very conclusive, the Navy Department decided to make still another trial before finally adopting the Harvey process, and in the latter part of 1891 two more 10½-inch nickel-steel plates were ordered from the Bethlehem Company, both of which were treated by the Harvey process and tempered by an improved method. These two plates differed in one respect, namely, the first having been forged to 12½ inches, and, after supercarburisation, being further reduced by forging to 10½ inches; the second plate was forged to final dimensions, that is, to 10½ inches, before Harveyising. The chemical and physical properties of the plates before treatment were the same. These plates were tested at Indian Head on July 23, 1892, under precisely the same conditions as those of October and November, 1891, and established not only the value of the Harvey process, but also that of reforging after supercarburisation, and it was determined that thereafter all armour for the United States Navy should be so treated.

Improvements in manufacture followed from time to time, and the so-called Harveyised plates held the lead in all countries until a modification of the process was made at the Krupp Works, in Germany, in 1895. The first important mention of the new Krupp process dates from the test of a 11.8-inch plate at the company's proving ground at Meppen on September 15, 1895. From published statements, the plate above referred to showed unusually good ballistic qualities and such immunity from cracking that it was referred to as the champion thick experimental plate.

The principal British manufacturers acquired the process, and in 1897 Messrs. Vickers, Sons & Maxim, Ltd., of Sheffield, presented for official test an 11 11-16-inch and a 6-inch plate, both of which gave excellent results and fully bore out the reputation which the new Krupp process had attained in Germany. Other British manufacturers presented plates made by the new process, and the superiority of the new armour was so fully established that its adoption became an assured fact. It became merely a question of the ability of the manufacturers to produce it, as its manufacture necessitated extensive alterations in the then existing armour plants.

The American armour manufacturers, having acquired the rights to use the new process, submitted, in July, 1898, the first Krupp plate manufactured in the United States, the credit for so doing belonging to the Carnegie Steel Company, and in October of the same year the Bethlehem Steel Company also submitted an experimental plate, both companies following with second plates. The tests of these plates showed their excellence, and also that the American manufacturers could produce armour by the new process equal to that made abroad.

The Krupp process is, in fact, an improvement on the Harvey process, and the alloy used is referred to as nickel-chrome, as both of these metals enter into its composition. The supercarburisation of armour plates made by the Krupp process, is produced either by means of a hydro carbon gas or of solid carbonising materials, such as are employed in making the Harveyised plates. Krupp plates are not only tougher and more resisting than Harveyised plates, but they have the pecu-



A COMPLETE 8-INCH GUN TURRET OF THE U. S. BATTLESHIP "MASSACHUSETTS", MADE AT THE CARNEGIE COMPANY'S HOMESTEAD WORKS, PITTSBURGH

liarity of not cracking under heavy impacts. This is a matter of great moment. The superiority of armour plates manufactured by the Krupp process is more apparent in the case of thick plates than in thin ones, and it is an open question whether in plates of not over 5 inches in thickness the Harveyised plates are not equally as good. The American armoured ships now building and those about to be commenced will all carry Krupp armour for all plates over five inches in thickness, and possibly for some of the thinner plates.

For a number of years the cost of armour plate has been under discussion by both Houses of Congress, and various restrictions were imposed, which led to many complications and delays in the completion of vessels under contract; but the Act of June 7, 1900, provided, "That the Secretary of the Navy is hereby authorised to procure by contract armour of the best quality for any or all vessels above referred to, provided such contracts can be made at a price which, in his judgment, is reasonable and equitable; but in case he is unable to make contracts for armour under the above conditions, he is hereby authorised and directed to procure a site for, and to erect thereon, a factory for the manufacture of armour, and the sum of four million dollars is hereby appropriated towards the erection of said factory."

Under the above provisions the Secretary of the United States Navy, after public advertisement and prolonged negotiations, made contracts for 37,184 tons of armour, more or less, covering all the armour required for vessels authorised for which no provision had been previously made. The amount of armour previously ordered amounted to 35,773 tons, so that the total quantity of armour ordered for the ships of the new American Navy since July 1, 1887, amounts to 72,957 tons.

The following list shows the vessels to which this armour has been, or will be, applied, and the kind of armour carried by each:—

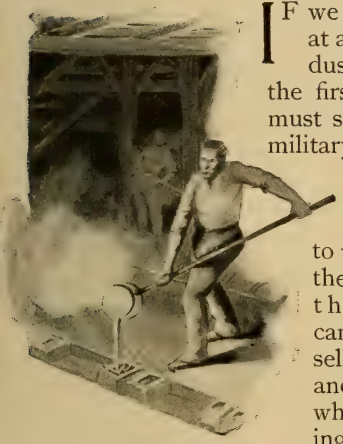
Amphitrite.—Double turreted monitor, 3990 tons displacement. Nickel-steel, not face-hardened.
Miantonomoh.—Double-turreted monitor, 3990 tons displacement. Compound, not face-hardened.
Monadnock.—Double-turreted monitor, 4005 tons displacement. Nickel-steel, not face-hardened.
Terror.—Double-turreted monitor, 3990 tons displacement. Nickel-steel, not face-hardened.
Puritan.—Double-turreted monitor, 6060 tons displacement. Nickel-steel belt, and nickel-steel Harveyised turrets.
Monterey.—Double-turreted monitor, 4084 tons displacement. Nickel-steel, not face-hardened.
Maine.—Second class battleship, 6648 tons displacement. Nickel-steel Harveyised.
Texas.—Second class battleship, 6315 tons displacement. Belt nickel-steel Harveyised; turrets nickel-steel, not face-hardened.
New York.—Armoured-cruiser, 8200 tons displacement. Nickel-steel, not face-hardened.
Brooklyn.—Armoured-cruiser, 9215 tons displacement. Nickel-steel Harveyised.
Indiana.—Battleship, 10,288 tons displacement. Nickel-steel Harveyised.
Massachusetts.—Battleship, 10,288 tons displacement. Nickel-steel Harveyised.
Oregon.—Battleship, 10,288 tons displacement. Nickel-steel Harveyised.
Iowa.—Battleship, 11,340 tons displacement. Nickel-steel Harveyised.

Kearsarge.—Battleship, 11,525 tons displacement. Nickel-steel Harveyised.
Kentucky—Battleship, 11,525 tons displacement. Nickel-steel Harveyised.
Alabama.—Battleship, 11,565 tons displacement. Nickel-steel Harveyised.
Illinois.—Battleship, 11,565 tons displacement. Nickel-steel Harveyised.
Wisconsin.—Battleship, 11,565 tons displacement. Nickel-steel Harveyised.
Maine.—Battleship, 12,500 tons displacement. Krupp chrome-nickel.
Missouri.—Battleship, 12,500 tons displacement. Krupp chrome-nickel.
Ohio. — Battleship, 12,500 tons displacement. Krupp chrome nickel.
Arkansas.—Single-turreted monitor, 3214 tons displacement. Nickel-steel Harveyised.
Nevada.—Single-turreted monitor, 3214 tons displacement. Nickel-steel Harveyised.
Florida.—Single-turreted monitor, 3214 tons displacement. Nickel-steel Harveyised.
Wyoming.—Single-turreted monitor, 3214 tons displacement. Nickel-steel Harveyised.
Pennsylvania.—Battleship, 15,000 tons displacement. Krupp chrome-nickel.
New Jersey.—Battleship, 15,000 tons displacement. Krupp chrome-nickel.
Georgia.—Battleship, 15,000 tons displacement. Krupp chrome-nickel.
Virginia.—Battleship, 14,600 tons displacement. Krupp chrome-nickel.
Rhode Island.—Battleship, 14,600 tons displacement. Krupp chrome-nickel.
West Virginia —Armoured-cruiser, 13,800 tons displacement. Krupp chrome-nickel.
Nebraska.—Armoured-cruiser, 13,800 tons displacement. Krupp chrome-nickel.
California.—Armoured-cruiser, 13,800 tons displacement. Krupp chrome-nickel.
Marylaud.—Armoured-cruiser, 13,400 tons displacement. Krupp chrome-nickel.
South Dakota.—Armoured-cruiser, 13,400 tons displacement. Krupp chrome-nickel.
Colorado. — Armoured-cruiser, 13,400 tons displacement. Krupp chrome-nickel.
St. Louis —Protected cruiser, 9700 tons displacement. Nickel-steel Harveyised.
Milwaukee. — Protected cruiser, 9700 tons displacement. Nickel-steel Harveyised.
Charleston.—Protected cruiser, 9700 tons displacement. Nickel-steel Harveyised.

In addition to the foregoing a number of vessels of less importance, such as the *Olympia*, *Cincinnati*, *Marblehead*, and others, carry a certain amount of armoured protection in the shape of gun-sponsons made of comparatively thin nickel-steel plates. There is little doubt that further improvements will continue to be made in the quality of armour plates, but what the nature of such improvements will be it is impossible to say at this time.

THE ORGANISATION OF AN INDUSTRIAL UNIT

By E. H. Mullin



IF we glance generally at any organised industrial unit, one of the first things which must strike us is what military men would call the length of its front, with consequent liability to weak spots along the line. Between the preliminary canvasser in the selling department and the workman, who is, say, melting pig-iron to make castings, stretches a chain of intermingled men and appliances, the length of which is roughly proportionate to the size of the industrial unit under observation.

If this chain were composed of equal-sized links, joined together in a single straight line, a pull at one end would immediately be felt at the other, as well as at all the links between these points. But some of the links are large while others are small; the chain itself does not lie straight, but has numerous bends; and, to make the analogy approximately complete, at some parts of the line there may be four or five sections of parallel chains, instead of a single chain. The result is that no matter how great the force may be which pulls at the chain, its effect is liable to be dissipated by taking up the "slack," or by friction at the "bends."

If we could conceive the selected industrial unit as a simple chain lying straight between its ends, it would be a comparatively easy matter to keep it taut, and force applied at any point would be instantly transmitted throughout its length. Depreciation would be shown by the gradual elongation of individual links. A chain being no stronger than its weakest link, each link could be strengthened or replaced as soon as it showed signs of giving way; or, if it were deemed desirable, links stronger than before might be gradually inserted without impairing the continuity of the chain as a whole.

The chain, however, which is more analogous to the industrial unit which we have under consideration is not easy to keep taut, and it is not practicable to keep every link in full view, so that some parts of the chain are strengthened at one time and some at another, until, it is safe to say, there is not an industrial unit in the world in which the tension on the stronger links has not to be relaxed in order to avoid breaking the weaker links. We may put this fact in concrete terms by saying that in an industrial unit some departments,—whether production, selling, or what not,—have to be worked below maximum efficiency in order that other departments may not be overtaxed.

As all industrial phenomena represent the effect of man's mind upon inert matter, it is not strange to find that the infinite varieties of mind are much more apparent in surveying final results than the seventy elementary substances which compose the material of this earth. And, as self-acquired experience is a much commoner attribute of the human mind than the ability to grasp and utilise the experience of other minds, we find that the average mind is apt to strengthen those links of the chain of an industrial unit along the part where its self-acquired experience is greatest.

Thus, to take an illustration from the production department of a locomotive works, the mind in charge whose earlier experience has been chiefly with boilers

will be apt to reinforce unduly his force of boilermakers, where another mind with a different experience would lay stress upon the motive parts, or a third mind upon the framework.

In an earlier day it was possible for a connoisseur, with plenty of money, to note nice distinctions of quality between manufacturers, and, say, in the case of a gun, to buy the barrel from one gunsmith, the lock from another, and the stock from another, obtaining in this way the most perfect gun which could be made. But economical production under modern industrial conditions forbids us from selecting the different parts of a machine from different manufacturers, even where the strong and weak points of individual manufacturers are generally recognised. We are forced to take average complete machines. made under the direction of average minds, and, therefore, characterised in each case by strengths and weaknesses. It will follow, however, that the mind of rare ability will rather distrust its self-acquired experience and will pay greater attention to every part of the chain other than that with which it is thoroughly familiar.

This last point may be pushed farther with advantage. The mind which has risen through, say, salesmanship to be the commanding force in an industrial unit, will be apt to strengthen unduly the selling end of the chain, either weakening the production end through hurtful economies, or allowing a subordinate mind such free play that the production end will become an undue tax on the selling end. In the first of these cases the increased efficiency of the selling end will be absorbed in disposing of inferior goods; in the second case, it will be dissipated in obtaining the higher prices demanded on account of factory wastefulness. In either case the increased efficiency of a part fails to give results through want of co-ordination throughout the whole. In fact, co-ordinating power is the indispensable need in an industrial unit if its work is to be successful, and the duty of this power is to keep the tension on the links of the chain as evenly distributed as is practicable. It may easily be seen that the longer the chain of an industrial unit, the more likely the co-ordinating power will be not to keep every link in proper tension at all times. It follows, therefore, that each link must have within its own sphere a sub-governing power as nearly independent of outside control as possible. But just in proportion to its self-contained efficiency will this sub-governing power of each link tend to exhibit that excess of zeal which the French call "the defects of its qualities." Thus, for example, the selling link will endeavour to sell goods at prices other than those which represent their true market value; the production link may want shops which will be renowned for their excellence rather than for their strict adequacy to the work in hand; the purchasing link will be tempted to buy raw materials because they are cheap rather than because they are precisely what is wanted in any given case.

All these excesses must be kept constantly in check by the co-ordinating power; but to save the time which would be lost by continual appeals and decisions in specific cases, the co-ordinating power gradually builds up a series of rules and understandings which constitute what is generally termed the internal policy of an industrial unit. At the head of the co-ordinating power stands the commanding force which receives impressions from without and within, reviews the past and foresees the future, and by the aid of experience and reflection bends the industrial unit into such a shape that it may best accomplish the object in view.

Broadly speaking, all industrial units exist to sell something at a profit. The railway unit sells transportation; the gas unit sells light or heat; the manufacturing unit sells goods; and even the banking unit sells only the use of money. But the need of a commodity must exist before it can be supplied at a profit, and, therefore, buyers must precede sellers. Moreover, the needs of mankind have been approximately the same since the foundation of the world, and progress in the industrial arts has consisted either

in new modes of gratifying man's needs or in the reproduction of old modes at a smaller cost. For example, the great electrical industries which have been built up during the past few years supply either light or power in a more convenient form than was possible before their advent. But history does not record the time when man did not have fire, or when he had not discovered the useful properties of the horse as an external source of power.

On the whole, the greatest factor in the growth of modern industries has been their power to produce more and more cheaply as the years roll by. Mr. Abram S. Hewitt calculated a few years ago that the discovery of the Bessemer process of making steel had added as much to the capital of the world in forty years as the entire capital existing in the world prior to that time. Suppose the iron mines of the globe had been at the point of exhaustion at the time of Bessemer's discovery, of what use would it have been? It is a truism that the luxuries of to-day become the necessaries of to-morrow, but this is mainly because what is dear to-day will be cheap to-morrow. And experience teaches us that decline in price increases the sale of an article which supplies a real human need, in something like geometrical proportion, and not merely in arithmetical proportion, as might be expected. It follows, then, that promoting the cheapness of any product is an end desirable in itself because it tends to broaden markets and to convert luxuries into necessaries, thus giving a surer base upon which organised capital can operate.

The great decline in the price of commodities by which the nineteenth century was distinguished from all its predecessors was due almost entirely to the utilisation of mechanical power. In the United States to-day one mechanical horse-power can be purchased in bulk for $25 per annum. One man-power, working 300 days a year for ten hours a day, will cost, at the very lowest, $300. Assuming that the work done by a horse-power is equivalent to the labour of six men, we may easily figure out that seventy-two horse-power may be purchased for the same price as one man-power.

But this does not express nearly the whole gain. Mechanical horse-power can be concentrated in any desired quantity at a single point, or can be distributed to do work at a thousand points. Under the inspiration of this flexibility have grown up all the wonderful inventions in automatic machine tools, the characteristic feature of which is to save time, power and material in manufacture and in which standardisation of product plays an important part.

It is a mistake to think, however, that what is now known in the industrial world as standardisation has arisen from the development of modern machinery. Primarily, standardisation is the attempt of the human race to save brains, which are dear and scarce, at the expense of hands, which are cheap and plenty. The first set of flint arrow-head makers in the palæolithic age were artists and inventors; tne second set were artistic imitators of the first set; the third set were common labourers making the standardised article by rule of thumb.

The only real organised units of men in early history were armies, and we see in the Roman legion, for example, the standardisation of weapons. And it is a remarkable fact that we owe the great development of modern automatic tools to the impetus which such inventions received in the New England section of the United States through the pressure to get rifles quickly during the American Civil War, in the sixties.

Modern standardisation of machinery was made possible by the manufacture, by Sir Joseph Whitworth, of measuring instruments of sufficient accuracy to make the variation between like parts turned out from the same machine not more than one-thousandth of an inch. The standardisation of parts is an economical gain so long as its practice does not operate to prevent designs based upon new inventions from being carried into effect on account of the cost of their production in upsetting existing standards.

But it must not be forgotten that,

looked at from one point of view, standardisation is equivalent to crystallisation, —that is, the death of invention so far as the standardised part is concerned. Imagine, for example, a newly invented screw machine which would turn out screws at half the present cost, but only at a pitch different from the standards now in use. It would take years of effort and a lavish outlay of capital to overthrow the vested interests which have grown up around the present standard pitch of screws. Moreover, in the broadest sense, the industrial unit which runs to as nearly as possible complete standardisation of its products is in great danger of having ultimately a set of automatons turning out its work, so that when improved processes, demanding intelligent skill, come up, the unit is found wanting in flexibility and adaptability, and is, therefore, easily passed in the race by some younger rival which has not had the chance to make standardisation a fetish.

Broadly speaking, standardisation should be restricted to parts and should never be applied to wholes. There is a large locomotive works in the United States which has preserved all its patterns and working drawings for over half a century. When an order for a new locomotive is received, the pattern index is searched, and so great is the accumulation of patterns and so narrowly restricted is the originality of superintendents of motive power that it now rarely happens that all the patterns necessary for the building of that particular locomotive are not found in the pattern "library," as it is called. This is as near an approach to the ideal in manufacturing as it is possible to reach, because any number of not standardised whole locomotives can be assembled out of standardised parts, and there is, thus, great flexibility of type in conjunction with the utmost cheapness in the reproduction of parts.

Looked at in its wider aspect, standardisation must be held responsible for great economical waste, as well as great economical saving. The advent of trades-unionism was of great service to artisans by fixing minimum prices for their labour. But in its full development trades-unionism has tended both to raise the level of inferior workmen's wages above their economic level and to fix a limit to the remuneration of the best workmen. The effect of this is to curb the ambition and energy of the best workmen in the sphere where their valuable experience has been gained, and the result is that the best workmen become indifferent foremen, or become rolling stones, or remain where they are and turn lazy. The standardisation of mechanical products also implies a certain waste of material, compensated for by cheapness in the cost of manufacture, since, on the average, no article will be the exact size needed, but the next larger standard size.

It has been already pointed out that the weakness of the modern industrial unit is proportionate to the length of the chain which stretches between the purchase of the raw material and the sale of the finished manufactured product. As each link in this chain must be strong enough to carry its own burden, it necessarily develops its own ideals of efficiency. Put in another way, each link is under constant temptation to make the means which it subserves an end in itself.

Take, for example, shop-costs keeping systems! Both theoretically and practically nothing can be more important for the vigorous and healthy life of an industrial unit than exact knowledge of how much it costs to manufacture any given article. But the acquisition of this knowledge ought to be limited by two factors. When the extra book-keeping charges of a shop-costs keeping system become magnified to the extent of adding more to general charges than is saved by the introduction of the system, it is evident that an economic loss is incurred. Again, when a shop-costs keeping system operates to divide the workman's mind between the work in hand and its statistical bearing, he is only too liable to fritter away the cream of his energy on mere figures. Moreover, like all other forms of red tape, there is the danger that any particular form of shop-costs keeping system will

harden and become standardised quicker than the actual work to be done, and will, therefore, be wanting in the necessary flexibility and adaptability to give accurate data after it has been in force for any considerable length of time.

It is well to bear in mind that present factory systems are not yet a hundred years old, their rise being based upon the modern utilisation of the steam engine in conjunction with the remarkable mechanical inventions which were made toward the close of the eighteenth century.

The immediate effect of these inventions was to extinguish cottage industries by the competition of the power loom and the spinning frame in textile manufactures; gradually to replace the blacksmith and the whitesmith with ordered companies of mechanics and fitters in machine shops; and to substitute for the small foundry huge blast-furnaces and rolling mills.

During the transition the workmen had first to pass through a stage not far removed from slavery, when they were completely at the mercy of unscrupulous employers. The organisation of trades unions and legislative prohibition of child labour marked the beginning of a better state of things, giving, in effect, a minimum wage. Then followed piece work, which insured to the workman some proportionate return on his product. Finally, we seem to be on the eve of a general adoption of what is generally known as the premium system, the essence of which is a limited copartnership between employer and employed to divide the profits of time saved in the use of power and tools. We seem thus to be approaching the pre-factory condition of things, when the individual workman sold the product of his skill and industry, but did not sell his time as an item by itself.

The next natural step ought to be the frank acknowledgment on the part of workmen of the risks to which money invested in plant and raw materials is subject and the necessity for its adequate reward as an inducement to investment.

As already pointed out, without brains money is useless. We may now go farther and say that added to these two factors there must be the hope of an adequate reward before a modern plant is erected and the first pay day arrives for the assembled workmen. The commanding mind who directs the investment of the money has before him a number of alternatives. He may select a broad market in which competition is necessarily keen, and in which, therefore, profits must be small. In this case his hope of success lies in manufacturing cheaper than his competitors, so that he may, if forced to, undersell them and still make a profit. Or he may choose a narrow market in which profits are large, but in this case he must divine so exactly the needs of his market that his goods will obtain an instant preference over those of his competitors, and that they will be able to retain this preference in dull times when narrow markets are apt suddenly to become very much narrower. On his skill in management, in the layout of his factory, in the amount and quality of product which he obtains from his workmen, depends the success or failure of the industrial unit of which he is the moving spirit.

How small the difference between prosperity and bankruptcy may be is seen in the case of great railway systems where it is marked by the saving of one-tenth of a penny in hauling a ton of goods one mile; or in large steel works where the difference of one-hundredth of a penny a pound means a profit or loss of millions per annum. With such delicate adjustments it is no wonder that everything counts.

The ideal aim, in a machine shop, for example, is to keep every tool running to its full capacity. A business requiring machine shops may, therefore, come to grief by the interest charges on special tools for which there is not a constant supply of work. A thousand men habitually starting work five minutes late, or quitting it five minutes early, mean the equivalent of a loss of 2500 working days in the year. A loss of half a pound of coal per horse-power-hour in a thousand horse-power steam plant means a loss of a thousand tons of

coal per annum, besides the additional cost for the labour of handling the coal and ashes.

It has often been said that the margin of profit in a large factory depends upon the success of the management in "stopping the leaks." It is almost axiomatic that the larger the industrial plant, the greater the leakage, not only in materials abstracted or wasted, but in time lost by workmen, in inefficiency developing now in one part of the factory, now in another, whereby cost is unnecessarily increased. But is this not merely the other side of the economies effected by superintendence on a large scale? The small factory costs relatively more than the large one for supervision, but the men at the head of a small factory have a much better chance of gauging the capability of each individual workman, of remedying faults before they become disasters, of "stopping leaks" in every direction. Put in another way, factories have inertia in proportion to their size and the complexity of their products, and a point must be reached where the ablest factory manager has not force enough to keep overcoming inertia as fast as it arises.

Herbert Spencer is fond of pointing out that in the evolution of life from the protozoon to the highest mammals there has been a constant progression from homogeneous undifferentiated protoplasm to heterogeneous living matter with specialisation of function. At first, all five senses resided in the same cell,—each cell did everything for itself. In man,—the highest and last of Nature's products on this earth,—we find the cells differentiated into bones, muscles, blood-vessels, nerves, and,—beyond all, —a brain.

The industrial unit which ought to stand the greatest chance of success will be that most nearly patterned upon Nature's methods, as far as it is possible by analogy to apply them. We may, first of all, ponder upon the fact that, though man is the highest of Nature's products, he is far from being the most highly specialised. The hawk has better sight; the dog has keener scent; the cat has finer sense of hearing, so that man is where he is, not by the development of his senses, but because he has a reflective brain. Yet so carefully is man fitted out to play his part in the world that he has two distinct brains,—an automatic brain and a voluntary one. The automatic brain takes care of his heart-beats, co-ordinates his movements in walking, and manages his whole internal economy as long as all goes well, reporting at once to the voluntary brain as soon as anything goes ill. The voluntary brain, thus freed from the drudgery of the constant supervision of details, is a kind of supernatural registering machine which incorporates instantly the experience of the moment with all its past experiences, thus guiding each man to choose the path of least total resistance to his ultimate goal.

The two brains of man, together with the afferent and efferent nerves which receive impressions from the senses and convey orders to the body may be likened to the general staff of a great modern army. The afferent nerves thus resemble the intelligence department which conveys correct impressions to the head of the general staff, while the efferent nerves resemble the executive officers through whom orders are carried out.

But, as Napoleon has said, in war men are nothing; a man is everything. So, in the modern industrial unit, everything must ultimately rest upon one man, one brain, one mind. And the resemblance between great complex industrial units and modern armies becomes closer every day. The "sinews of war"—or, in other words, money—plays an equally great part in both; maximum efficiency throughout for a given time is equally an ideal; the quick massing of forces at the vulnerable spot for attack or defense is equally requisite; foresight, calculation, energy, decision are qualities equally in demand.

Yet in our modern industrial units what should correspond to the general staff of an army is mostly wanting, or is present only in the most rudimentary form.

THE ENGINEER IN THE KITCHEN

By Reginald Pelham Bolton

IN the course of designing the services of large hotels and apartment houses, no subject has presented more perplexity than the arrangement of the kitchen, not so much in respect of any inherent difficulty in the problems involved as on account of the custom which has hitherto prevailed with owners of delegating the decision of all arrangements to the particular steward or chef who is engaged for the operation of the department. In addition, it has been the habit of architects to refer the proportions and extent of apparatus to manufacturers of sundry appliances, and to allow only the barest space necessary for their installation.

The employees referred to, however intelligent in handling what they have been accustomed to, are not capable of grasping the requirements of a new disposition and are commonly unable to read proportions from scale plans. Usually they are controlled by the idea of reproducing the particular elements to which they have been used in their previous situation, and insist on trivial dispositions to bring about a likeness to their old quarters. Thus the blunders and errors of one establishment have been reproduced in others, and nearly every large hotel kitchen may be seen to be proportioned and arranged in a way that causes useless traffic and loss of time. Having witnessed this course of affairs on several occasions, the writer has come to the conclusion that the problems of kitchen service offer a considerable field for the ingenuity of the mechanical engineer, and that the subject is best to be dealt with and the best results are to be obtained by engineering knowledge and judgment, and by practically ignoring the prejudices and opinions of chefs, cooks and stewards. This course has been followed in several instances with success, and in the end with greater satisfaction to the owner and operators, and with a reduction of labour and material, so that the design of kitchen work may now be regarded as a branch of engineering practice.

The kitchen and offices of a modern restaurant or hotel are run upon fairly well-defined methods. The staff consists of a steward, in whose hands are vested the general management, the purchase and handling of materials, and the accounting for moneys, wines, and liquors. His subordinates are the chief waiter, responsible for the waiting service; the bill and cash clerks, through whose hands the outgoings and income pass; and last, but not least, the chef, paramount in the actual control of the cooking, baking, and other culinary and edible departments.

All large kitchens now not only cook, but provide their own baking and ice-cream making, cold storage of provisions, and cutting up of meats from the carcass. These involve a large number of appliances, to be placed in such position as will render them accessible to cooks, operators, and waiters.

The general proportions have to be first settled by reference to the number of tables to be served and the resultant corps of waiters. Upon this can be based the number of fires in the main cooking range. These are largely over-

THE MAIN RANGE IN THE KITCHEN OF THE WALDORF-ASTORIA, NEW YORK. THE LARGEST AND MOST SPLENDIDLY EQUIPPED HOTEL IN THE WORLD.

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proportioned in existing kitchens. Whatever number may be provided, and whatever cooking be required, it will be found that the cooks will keep all fires alight, and could turn out all their requirements on a less number.

The ranges are provided with ovens, and are supplemented by broilers, to which a separate cook is generally assigned. In front of the range the cook's table is set, fitted with steam-heated pans, known as "bain-maries," in which food already cooked is kept hot, under cover and carved. From these pans and from the cooking food vapours arise, the extraction of which from the kitchen is a necessity, if the odours are not to be allowed to work through the building.

For this purpose the kitchen must be isolated from the dining-rooms or any part of the house by double swing-doors, or by an intermediate room utilised as a serving room, in which a steam-heated table is provided on which food can be kept warm while waiting. This provision cuts off free egress of the hot kitchen air, and if a strong suction be applied near the range, the currents of tainted air may be withdrawn in that direction.

The problem is complicated, however, by the necessity of introducing fresh air in kitchens located underground. In one instance no less than 16,000 cubic feet per minute of cold fresh air are forced by fans into an underground kitchen, and even in winter the temperature of this air does not require to be raised. At the same time, about 12,000 cubic feet are withdrawn by fans, the balance being required for, and utilised by, the fires of the ranges and baking ovens.

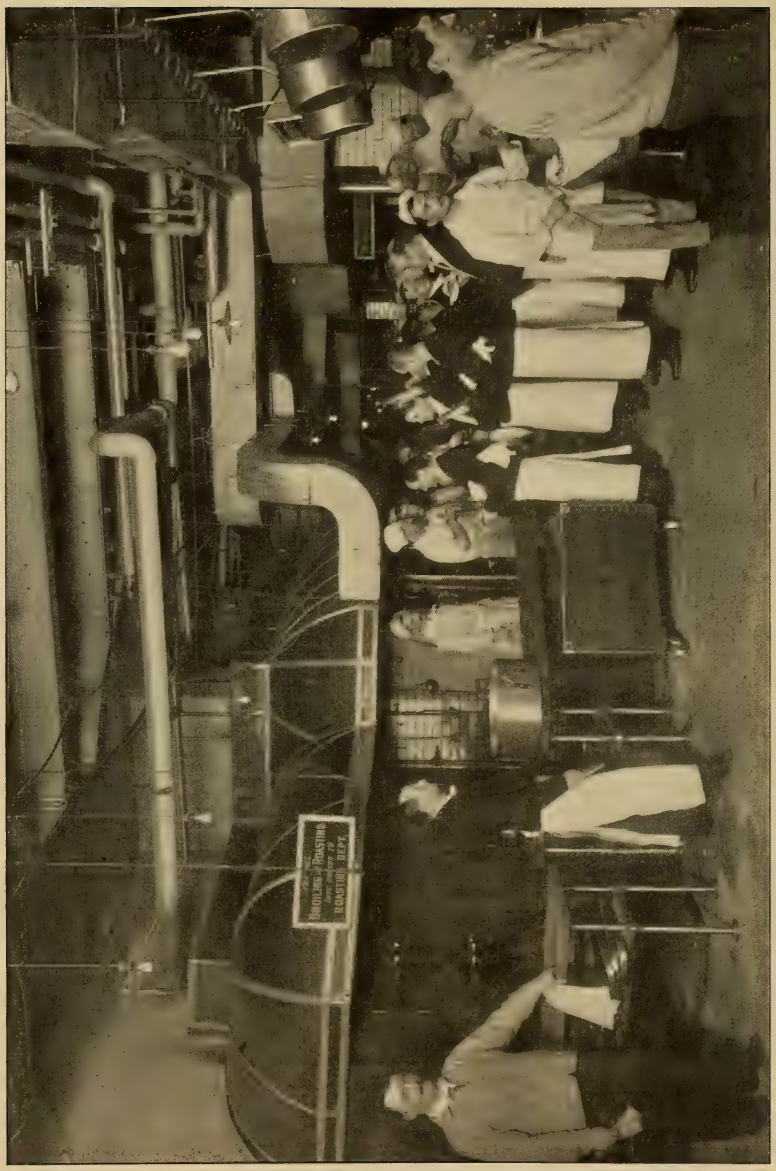
The modern kitchen comprises a large number of appliances, which, in the course of the past twenty years, have been undergoing development. The cooking range remains of much the same general type, but is now heavier throughout, and is arranged with fire-pots made of massive blocks of baked fire-clay, and with mechanical grates, rocking or shaking the clinker and ashes from below the fire, for which anthracite is largely used and forms an ideal fuel. The use of gas for large cooking is not widespread, although it is utilised in broilers. For these, however, many cooks insist on the use of charcoal as superior.

The chimney or flue for the draught of ranges is very usually proportioned in a haphazard manner without reference to the actual consumption of coal. The gases of combustion enter the flue very hot, and thus very small flues are made to do effective work. But if properly proportioned, and provided with suitable dampers, a considerable reduction could be effected in the necessary temperature required to produce the draught.

In several instances the writer has connected the ranges to the boiler chimney with beneficial results. There has been no attempt to make other uses of the waste heat of the ranges, but no doubt considerable heat might be disposed of in several useful directions.

Soups and vegetables are cooked by steam coils in suitable iron and copper kettles or pots, mounted separately on iron stands and grouped together under a large hood designed to catch the steam and vapours which arise in considerable volume. The disposition of the waste from these utensils, composed largely of greasy material, is one of the difficulties of kitchen design and management. With the waste of the scullery, where the pots and other utensils are washed, the discharge is apt to congeal in any system of pipes and cause a stoppage. For this purpose a device known as the grease-trap is used, consisting of a closed iron receptacle through which the greasy waters pass, and overflow beyond a baffle-plate. The receptacle has a water jacket through which the cold water supply of the various kitchen fixtures is caused to pass, thus chilling the floating grease, which can be then removed from the upper part of the chamber at intervals. The grease is of considerable value for soap-making, but as it is usually considered a perquisite of the chef, its economy has to be ignored.

As so many kitchens are below the level of the sewerage system, the wastage has to be elevated from some receptacle into which it is led. Various sewage-lifting devices are employed, in



ANOTHER WALDORF-ASTORIA HOTEL KITCHEN VIEW. BROILERS AND ROAST COOKS

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which compressed air, or ejectors operated by steam, or centrifugal pumps are the agents.

Near the cook's table is a refrigerator, fitted with shelves or small drawers, in which the cooks can keep their materials handy for instant use, and in this position the cost of maintenance of a low temperature may be readily appreciated.

The butchers' shop is arranged close to the broiling end of the ranges, and is provided with cutting-up blocks and tables, and with sinks in which to wash meats and chickens coming from cold storage. It has, of course, a special refrigerator for cut portions of meat, the carcasses being kept in a separate large storage room.

On the other side of the ranges is the scullery where very large sinks are used for the washing of the kitchen utensils, and a great amount of water is run to waste. In a suitable place for the reception of used articles are the dish-washing machines, of which a number of designs exist. The process of "washing up" after a meal is so well known and so undesirable an accompaniment of housekeeping that its accomplishment in a large establishment without the use of machinery may be recognised as a very thorny task. The plates, as received from the waiters, are scraped by attendants of their contents, the debris falling through holes in the counter into garbage cans, a rough selection being made by the scrapers. This garbage is promptly removed as the cans are filled, and is now usually placed in a refrigerated chamber where it is so chilled that no vapours or odours can arise from it previous to removal. In the largest hotels furnaces for its destruction are being utilised as auxiliaries to the service, and in one establishment, where the wastage of all sorts is expected to exceed two tons a day, the heat so generated forms an auxiliary source of power.

The dirty plates are stacked in wire baskets, elevated by a pulley, and dipped into boiling soapy water, agitated by a mechanical device or by jets of water or steam. The material on the surfaces of the plates is very thoroughly removed in a few seconds, and is followed by a plunge into another receptacle containing a flowing supply of agitated clear boiling water. Thence they emerge dripping, but very hot, and rapidly dry without handling, requiring only a slight polish with a cloth before being replaced in the heated closets ready again for use.

Those required for cold materials are put in a chilling closet and are reduced in temperature. Glassware is usually hand-cleaned, but where very large numbers of pieces are used,—and a large bar will send out more than 10,000 glasses a day,—a machine is employed, very similar in general operation to the dish machine.

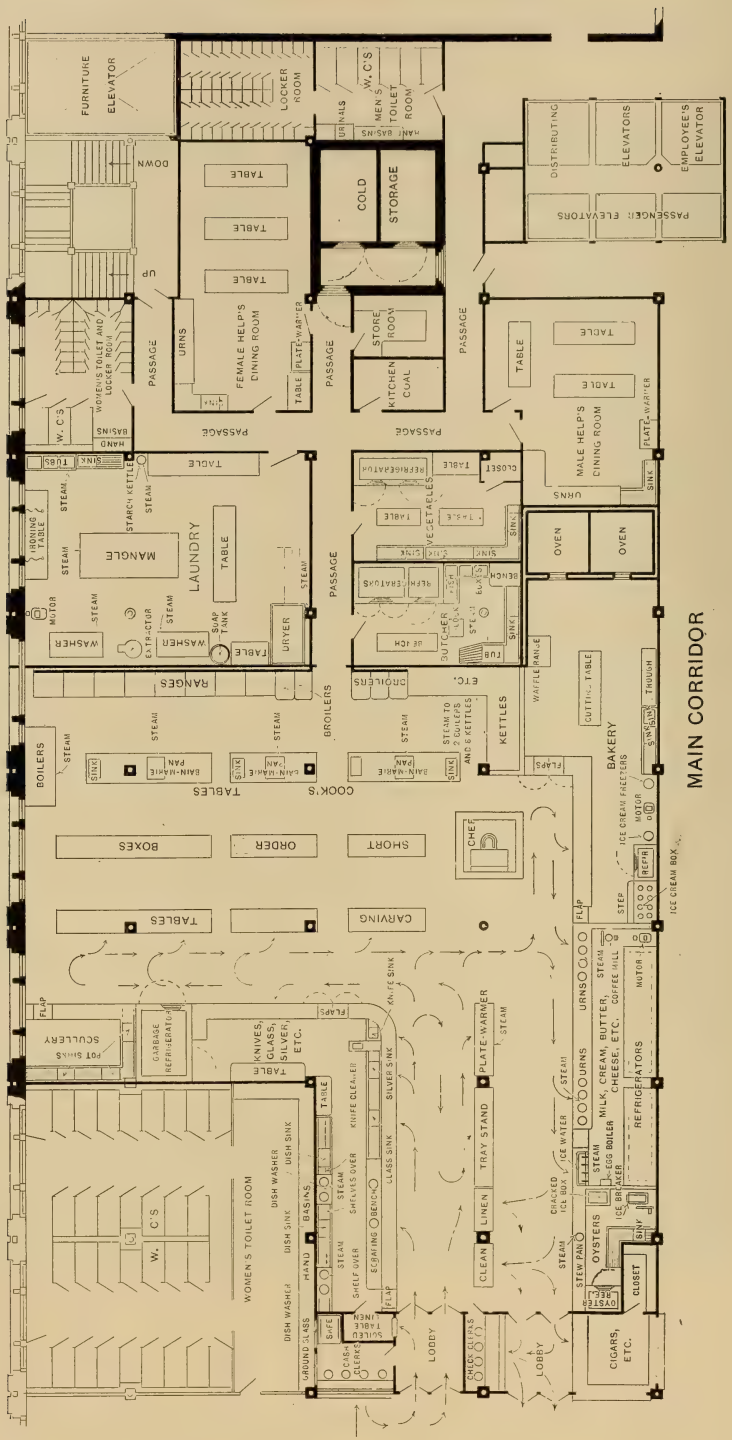
The breakage of china and glassware is a serious element of cost, and is largely to be guarded against by proper attention to its handling out and in. Constricted passages, stairways, and dumb-waiters are the cause of much loss in this direction.

The silverware and cutlery are separately cleaned by hand-washing, but the buffing and polishing are now done by mechanical appliances, generally operated by electric motors. The silica and emery dust from the buffing wheels have to be dealt with and prevented from circulating in the kitchen.

The next important department to the cook's is that of the baker, the official in charge being an autocrat in his own line, inferior only to the chef. It is now usual for large establishments to make their own bread, rolls, and pastry. Ovens for these purposes are of numerous and various designs, the chief differences consisting in the general construction. A solidly built brick oven is as much favoured by one as a more modern iron-framed and lighter construction is by another.

The exigencies of space have introduced double-decked ovens from which excellent results are obtained. The regulation of temperature, and of humidity inside the baking chamber, is now very complete, air and steam being introduced at the will of the operator.

The kneading process continues to be largely done by hand, though in the largest kitchens machines can be utilised.



AN APPROVED KITCHEN PLAN FOR AN AMERICAN DEPARTMENT STORE BUILDING

The baker has charge of the peculiarly American department of ice-cream making, which nowadays involves quite an extent of appliances. The use of shaved ice has been superseded since the writer adopted, in one case, the method of circulating the cold brine from the refrigerating plant around the outer chamber of the ice-cream freezers. The new system is likely to entirely displace the old methods, and is much superior to them in its capacity and control, as well as in the absence of salt and melting ice. The ice-cream, when mixed and made, is stored in cans in a refrigerated box, and from it are made up those ingenious and seductive iced puddings and shapes which evidence the highest art of the modern baker. These have to be maintained at a very low temperature in order to retain their shape, and special provision has to be made to keep them frozen hard.

The general arrangements include a counter at which tea, coffee, chocolate, milk, and hot water are served from steam-heated urns, the drinking mixtures being made by water pipes with valves connecting the urns. The cold meats and sundries, and the oysters, form separate departments, each with their respective cold storage boxes. Oysters are steam-cooked, and eggs are boiled in automatic steam-heated boilers, set to boil to the precise desired extent.

All the culinary operations are naturally dependent for their success upon the supplies of water and steam, removal of condensed water, and, in a large degree, on proper lighting and ventilation. Their relative position and extent, and particularly their ready access in suitable order of requirements, are of main importance. All these are subservient to the requirement that the whole service, in and out, shall pass a point where the outgoing materials shall be under the eye of the bill clerk, so that all may be accounted for.

The modern system of billing the waiter's supplies is an American development and is admirably efficient. Every article being priced, the bill clerk is provided with a box of metal or rubber stamps of prices, and the waiter on carrying out any order presents a numbered card devoted to the customer then being served, on which is impressed the value of the article he has received in the kitchen, the same value being stamped against the waiter's name on a bill sheet. From these he makes up his bill to present to the customer, and the bill when paid, being turned into the cashier in the restaurant, is compared with the waiter's bill sheet and card, and the total which he has to pay in can be promptly checked and computed both by the clerks and by the waiter.

The amount of service to be obtained from one waiter or waitress is largely dependent on the arrangement and relative location of the dining-rooms and kitchen. From the distance which some establishments provide, considerable waste of time and energy results, and the help are made to travel over a great amount of ground. The writer has suggested for several years,—but it is only just beginning to be appreciated by some proprietors,—that mechanical appliances are capable of improving the service in the dining chamber and of reducing its cost and extent.

The course of improvement will be in the direction of travelling conveyors, by which all used utensils will be returned direct from a central point, or points, in the dining-room to the cleaning departments, and there is no reason why the same methods may not be adapted to the delivery of food and drink into the dining-room, or at least to the serving-room. The kitchen would thus no longer be invaded by a stream of waiters. These would be replaced by a few trained servers, loading the conveyor at a central point, and the waiters would not be overheated, as they now are, not only by their exertions, but by entering the warm culinary departments. All orders would be transmitted in written form from a pneumatic station at the table, and all bill cards and bills returned in the same manner.

It is not too much to expect that the process of removal of table appliances will be effected by arranging for the entire table to be elevated through the

ceiling to a chamber above, whence it will be replaced by a newly set table top, or by the descent through an enlarged central table leg of the table contents, to be replaced by others on its return.

The elimination of the noise and clatter of the removal of dishes, and the improvement of the personal appearance and condition of the table attendants, may be thus effected within the next few years, and should place the service of modern restaurants on a higher plane.

These results will be attained if the subject is emancipated from the negligence with which it has hitherto been treated, and is dealt with as a matter deserving of trained technical attention.

ELECTRIC LIGHT AND POWER IN KOREA

By R. A. McLellan, Chief Engineer of the Seoul Electric Company, Seoul, Korea

THE KING OF KOREA

WHEN the fact is taken into consideration that the electric light and power plant referred to in the following pages is the first successful one in the Orient, and that it is in operation in Seoul, the capital of Korea, the land of the "morning calm," the "hermit kingdom," one cannot but conclude that the Koreans are about to shake off the lethargy of centuries and take on the progressive spirit of their Japanese neighbours.

It was in the autumn of 1898 that the first sod was turned for the building of the first street railway of Korea, and in the early part of May of the following year an official opening took place, a car was run over the road and the success of the enterprise, so far as the construction and operation were concerned, seemed assured. The cars were run by Japanese motormen and native conductors, and for a week all went well. The cars were crowded from morning until night, and for the first time perhaps in the history of Korea the inhabitants of Seoul had some means of enjoying themselves.

At the end of the week, a child, standing one afternoon near the track, was beckoned to by its father. Not thinking of danger, it ran in front of a rapidly moving car and was crushed to death. Instantly the superstition of the people was aroused; the foreign "devils" had introduced something among them from which nothing but ruin would follow; the traditions of their country were disrespected, and the calmness that had been with them for centuries was now visibly disturbed by this innovation. Within a few minutes after the fatal accident, therefore, the cars were attacked, and in a short time two were completely destroyed by fire. A rush was then made toward the powerhouse, with the view of demolishing that structure, for it was conceded by all that it was built on the rain dragon's back, which accounted for the severe drought that prevailed that season. Fortunately, however, they were prevented from carrying out their plans in that direction by the presence of two of

CARRYING MERCHANDISE

THE TROLLEY LINE ENTERING THE EAST GATE OF SEOUL

THE ROYAL PALACE AT SEOUL, FOUR HUNDRED YEARS OLD

the foreign railway officials, and a handful of imperial guards.

Immediately after this episode the running of the road was discontinued, the management concluding that, for a short time at least, foreigners would have to take entire charge of the plant, in order to insure the success of the enterprise. Late in the summer of 1899, therefore, the road was again put in service with American operatives, and has since continued at work uninterruptedly up to the present time. Accidents have occurred, occasionally followed by slight demonstrations of the people, but the antipathy is slowly giving way and the railway is beginning to be looked upon as a necessity.

The road, when first constructed, was about six miles long, and one of the principal reasons for its existence was that it was to carry His Majesty, the king, out to the tomb of the Queen, who was assassinated during the Chinese-Japanese war. This tomb is about three miles outside of the east gate of the city. But although a sumptuously appointed car was built expressly for this purpose, His Majesty has never ridden in it. The traditions of the country must be respected, and a plebeian conveyance like a modern street car was not to be thought of as a royal carriage. The machinery first installed consisted of a Babcock & Wilcox boiler of 125 H. P.; a McIntosh & Seymour tandem compound non-condensing engine of 115 H. P.; and a Westinghouse four-pole, 75-kilowatt direct-current generator. This machinery has been running nearly three years, averaging fifteen hours daily and has given no trouble, notwithstanding that, of necessity, it was left in care of the Koreans several hours each day. The road is now about nine miles long, with a 3′, 6″ gauge, single track and turn-outs at intervals of 3000 feet, the cars being run at intervals of 12 minutes.

The cars are built at Seoul from plans of American cars, with slight modifications to suit the conditions prevailing in Korea. A closed section in the center accommodates the first-class passengers, while each end is open and has seats running lengthwise. Twelve of these cars run from 7.30 A. M. until 11.20 P. M., and are well patronised by the people, especially in the hot summer evenings, at which time the service is barely sufficient to meet the demands. The generator for a large portion of the time is taxed twenty-five per cent. beyond its rated capacity.

In addition to the passenger cars

there are eight or ten freight cars, three of which are constantly in use, hauling coal to the power-house, taking away ashes, as well as doing a considerable amount of outside work for the government and private concerns.

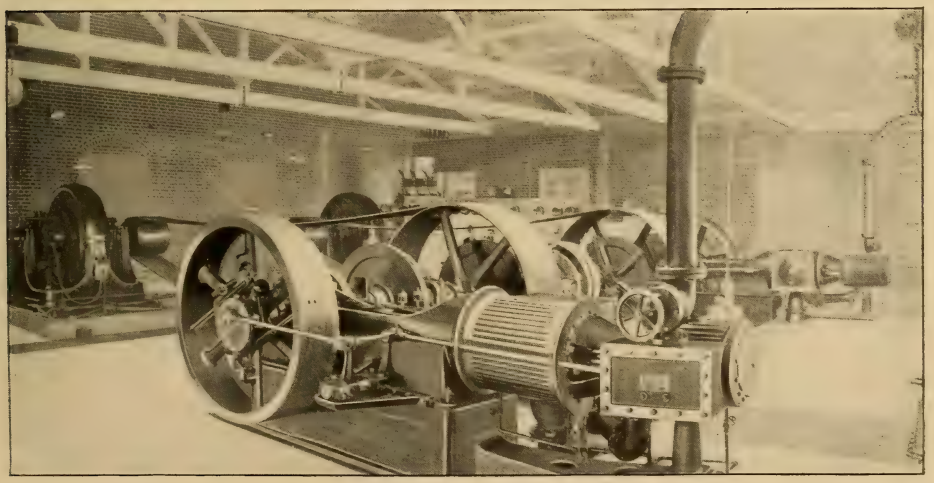
THE POWER HOUSE

Apparently not satisfied with this evidence of material progress, the king concluded that he must have something better than coal oil to light his buildings and palaces, for not a great time elapsed before Messrs. Collbran & Bostwick, the builders of the trolley road, were given a contract for the erection of a light and power plant combined, the first of its kind in the Far East.

Ground was broken for the new power-house in October, 1900, and in August, 1901, one of the officials of the palace opened the throttle of the engine, setting the new machinery in motion and giving light to 2000 incandescent lamps, ranging in candle-power from 16 to 150. Twenty arc lights also flashed up on the grounds and neighbourhood. It was a gala night for the people, and crowded in the power-house and about the adjoining grounds 10,000 Koreans watched with amazement the wonderful transformation scene, for the foreigners had changed night into day, and what they might do next was a matter of interesting speculation for the natives.

The new plant has now been running eight months, and in that time there have been but two short stops of one hour each,—a record which has gone far to demonstrate to His Majesty the reliability of electricity for illuminating purposes. It must be understood that if the king is satisfied with these Western ideas all others must be.

The new plant comprises an engine room 60 feet square, and a boiler room measuring 40 × 30 feet, both built sub-



THE POWER HOUSE INTERIOR

stantially of brick. There are two Babcock & Wilcox boilers of 125 H. P. each, while three pumps supply the water, one being specially piped for fire purposes. As the city of Seoul has not, as yet, any water works system, water is procured for the boilers and other purposes from two wells 12 inches in diameter and 20 feet deep, either one being adequate to supply the requisite amount of water.

There are two engines of 200 H. P. each, made by the Ball Engine Company, of Erie, Pa. They are tandem-compound, non-condensing engines, with 13″ by 22″ by 16″ cylinders, and run at 240 revolutions per minute. They are connected by a 6-inch shaft 23 feet long, through the medium of a friction clutch on each end; upon this shaft are mounted four driving wheels, two of 8 feet diameter and two of 4, the former driving the generators and the latter the exciters. All of these pulleys are loose on the shaft, motion being transmitted to them by friction clutches. This method makes the entire system as nearly interchangeable as possible. Changes have frequently been made from one generator to the other in 1½ minutes. The exciters also are wired in such a manner that they can be run in parallel, or either generator can be excited by either exciter.

The electric machinery consists of two 120 K.W. generators, or, more properly, rotary converters, driven by belt, supplying both direct and alternating current. The direct current, for running the street cars, has a pressure of 550 volts, while the alternating current voltage is 385. This latter current goes to two 62½ K.W. oil-insulated transformers, and being a two-phase current, the three-wire system is adopted to carry it to the different transformers in the city, it having been raised to 2000 volts. It is then lowered to the required 100 volts.

ONE OF THE PASSENGER CARS. THE CLOSED MIDDLE SECTION ACCOMMODATES FIRST-CLASS PASSENGERS

A sub-station, about three miles from the power-house, contains a 75 K.W. two-phase rotary converter—which is used on a branch line running down to the Han river,—a distance of about five

miles from the main line, to prevent the excessive drop in voltage that would otherwise occur. It is the intention of the management to extend the road about twelve miles further, terminating at a new site for the queen's tomb. This was recently selected by His Majesty, the present one not being a propitious one in the minds of the astrologers and advisors of his imperial highness. A portion of the machinery for this proposed extension is on the grounds, and work will soon begin. In addition to this material evidence on the part of the Koreans, indicating a desire to join in the march of modern improvements, the building of an extensive water-works system is now under consideration, and much preliminary work has already been done in connection with it.

THE DEVELOPMENT OF THE GALVANOMETER

By J. Wright

THERE is probably no piece of electrical apparatus which has been so developed and perfected during the last few years as the galvanometer. This may be defined as an instrument for measuring the strength of an electric current by the reactive force exerted between a magnet and a coil of wire through which the current to be measured is passed, one of the two elements, either the magnet or the coil, being fixed, and the other movable. Starting with the simple galvanometer or detector, consisting of a compass needle surrounded by a few turns of wire, we now possess delicate pieces of apparatus in which the movable element is supported by an almost invisible thread of cocoon silk, and so sensitive that they are capable of measuring the current produced by pressing two dissimilar coins together in the hand.

As far back as 1802, Romagnosi made a discovery which, though not

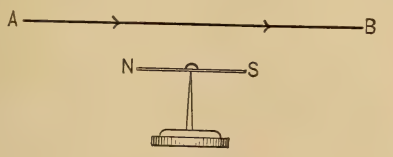


FIG. 1

published at the time, was rediscovered later, and culminated in the production of the galvanometer. Romagnosi's discovery related to the disturbing effect exercised on a magnetic needle by a voltaic pile or battery. It remained for Oersted, of Copenhagen, in the year 1819, to demonstrate the fact that a magnet tends to set itself at right angles to a wire through which an electric current is passing; further, he showed that the direction of displacement of the magnet depended upon the position of the wire, whether above or below the needle, the direction of the current being constant. With very simple apparatus, Oersted's original experiment can be repeated by any would-be investigator of the principles underlying galvanometer construction. He took an ordinary pivotted compass needle, *NS*, Fig. 1, and held above it, and parallel to it, a wire, *AB*, connected to a battery or other convenient source of direct current. On completing the circuit through the wire, the compass needle was deflected, the direction of deflection depending on the direction of the current in the wire *AB*. Thus, if the current were flowing in the direction indicated by the arrow heads, from *A* to *B*, the north extremity of the needle would turn to the East, that is, away from the observer in Fig. 1, and vice versa. A little consideration will show that if the wire *AB* be brought round in a complete loop below the needle, the effects will be additive, and the resultant force

upon the needle will be doubled. From this simple beginning to the well-known "detector" galvanometer, consisting of a rectangular coil surrounding a pivotted magnetic needle, was an easy stage, the first of its kind being known

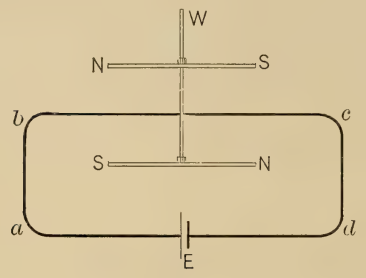


FIG. 2

as Schweigger's "multiplier" from the fact that the effect of a single turn of wire upon the needle was multiplied by the number of turns in a coil.

The next development resulted in increased sensitiveness and consisted in nullifying the effect of the earth's magnetism upon the needle, thus rendering it entirely subservient to the magnetic effects of the coil itself. It was due to Nobili, who applied the principle of astaticism to Schweigger's multiplier, thus rendering it independent of the earth's magnetism, which normally causes the needle to set itself in the magnetic meridian. Nobili constructed a pair of exactly similar needles and mounted them rigidly on an axis of brass wire *W*, as in Fig. 2.

It will readily be seen that the effect of the earth's magnetic field on the one needle will be exactly counterbalanced by that on the other, and the "astatic pair" will therefore be free to move in any direction, according to the current passing round the coil *a b c d*, from the battery *E*, the effect on the upper needle being the same as that on the lower one. It is usual in later forms of the astatic galvanometer to surround each needle with a coil, the two coils being wound in opposite directions so as to exercise an additive effect upon the needles. Further sensitiveness was secured in Nobili's original instrument by suspending the astatic system through the medium of the wire *W*, from a fixed support by means of a fine silk fibre which reduced the friction due to the pivot, and rendered the error from that cause practically negligible. The instrument was mounted on a suitable base provided with levelling screws, and covered with a glass shade through which the deflections of the needle could be observed on a circular horizontal dial graduated in degrees.

We next come to the tangent galvanometer, in which the tangent of the angle of deflection of the needle is directly proportional to the current flowing through the coil. This result is dependent on the fulfilment of certain conditions which, omitting all theoretical considerations, are thus cited by Professor Ayrton:—

When (1) The needle is controlled by a uniform magnetic field.

(2) The diameter of the coil is large compared with the length of the needle.

(3) The needle is suspended sufficiently near the centre of the coil that the field which is produced by the current passing round the coil, is a uniform

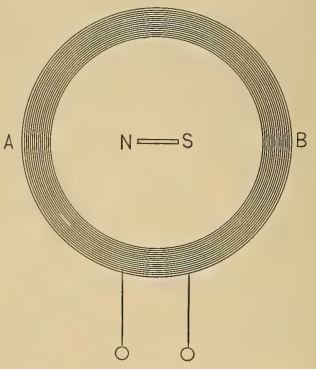


FIG. 3

one in the neighbourhood of the needle.

(4) The axis of the needle is parallel to the plane of the coil when no current is passing.

In order to secure these conditions, the tangent galvanometer is constructed as follows:—A truly circular coil, *AB*, Fig 3, from 10 to 15 inches in diameter,

consisting of a single turn of thick wire, or a number of turns of fine wire, according to the purpose for which the instrument is required, is constructed, and, at the centre of this coil, in a plane with it, is pivotted a short magnetic needle, *NS*, from three quarters of an inch to an inch in length. A light aluminium pointer is attached to the needle at right angles to it, and indicates over a horizontal scale graduated in tangents.

With a view to further securing uniformity of the field of a tangent galvanometer, Gaugain suggested placing the needle at a point on the axis of the coil, separated from the centre of its plane by a distance equal to half the radius of the coil, whilst Helmholtz still further improved on this idea by constructing a galvanometer with two equal and parallel coils, the needle being placed

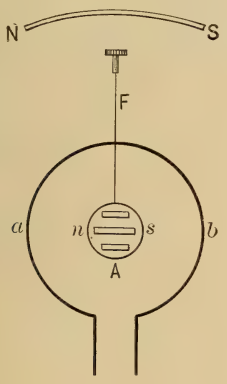


FIG. 4

on their common axis at a distance from either coil equal to half their respective radii. The ideal construction, as suggested by Professor Sylvanus P. Thompson, consists of three coils having a common axis, the centre one being of larger diameter than the other two, which are equal, and surrounding the needle, which is thus, theoretically, at the centre of a sphere whose surface is defined by the coils.

Following the suggestion of angular displacement conveyed by the tangent instrument, we come next to the sine galvanometer. Any galvanometer, the needle of which is controlled by the earth's magnetism, constitutes a sine galvanometer if provision be made for turning the coil about the axis of the needle. The method of usage is as follows:—The galvanometer is set up with its needle in a plane with the coil, i. e., they are both in the magnetic meridian. If now, a current be caused to circulate round the coil, the needle will be deflected; the coil itself is then turned bodily round in the same direction as the needle, whilst the current is flowing, and, at a certain point, overtakes the needle, and again lies in a plane with it. The sine of the angle through which the coil has been turned to effect this, is then a direct measure of the current passing round the coil.

The next important stage in the development of this useful piece of apparatus is to be found in Sir William Thomson's (now Lord Kelvin) mirror or reflecting galvanometer, which was first devised as an aid to submarine cable signalling, where the currents dealt with were often so slight as to defy detection by all ordinary forms of instrument. The mirror galvanometer, as originally constructed, consisted of a small concave mirror, about three-eighths of an inch in diameter, to the back of which were attached three or more short pieces of magnetised watch spring *n s*, Fig. 4. This light combination was suspended from a fixed support by means of a single fibre of unspun cocoon silk, *F*, in the centre of a coil, *a b*. Its normal position was controlled, and the earth's field counteracted, by a controlling magnet, *NS*, adjustably arranged on a vertical support above the coil. The indications of this instrument were read by means of a reflected spot of light, which, emanating from a suitable source such as an oil, gas, or electric lamp, was condensed by means of a suitable lens, and projected on to the mirror, whence it was reflected back on to a graduated horizontal scale in the shape of a rectangular or circular spot of light. The requisite definition is obtained by means of a fine black wire or thread stretched across the lens or aperture of emission, as a vertical diameter of the spot, and it is by the coincidence

of this line with the divisions on the scale that the deflections of the magnetic system are recorded.

Here we have an extremely light movable element suspended by a prac-

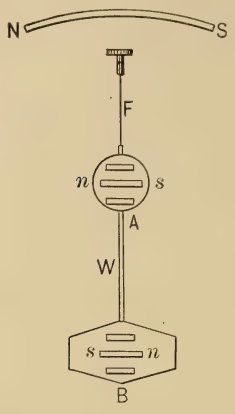


FIG. 5

tically frictionless support, and the length of whose index is limited only by the intensity of illumination and the focal length of the mirror *A*, which may be as great as six feet or even more.

The astatic principle has also been applied to the mirror galvanometer, two sets of exactly similar magnets being constructed, one of which is attached as before to the back of the mirror *A*, Fig. 5, whilst the other set, with their poles pointing in an opposite direction, is mounted on a light coffin-shaped mica vane, *B*. The two structures *A* and *B* are symmetrically and rigidly mounted on a vertical aluminium wire, *W*, and suspended, as before, by a quartz or silk fibre *F*. Two similar coils, wound in opposite directions, surround the mirror *A* and the vane *B*, respectively, and the latter is arranged in close proximity to the sides of a similarly shaped chamber, which can be completely closed or partly opened at will, thus regulating the motion of the air contained in it. In this capacity it acts as an adjustable damping device, whereby the oscillations of the suspended system are reduced to a regular and consistent period. Like the foregoing instrument this also is provided with a controlling magnet, *NS*, whereby its sensitiveness and normal position can be controlled and regulated.

It is obvious that galvanometers of the above type, with freely suspended magnetic systems, are unsuitable for use on board ship where the rolling of the vessel renders it impossible to maintain the system vertical. With a view to overcoming this difficulty, Lord Kelvin, then Sir William Thomson, designed his marine galvanometer, in which the mirror with its attached magnets, is suspended from above by a silk fibre as in the ordinary type, whilst a second fibre, attached to the lower edge of the mirror, is secured to a light fixed spring, which keeps the two fibres taut. The whole suspended system is fitted in a removable metal slide by means of which it can be bodily withdrawn when repairs are necessary.

Despite the great delicacy and utility of these instruments, they have one very serious drawback which materially combats their more universal adoption

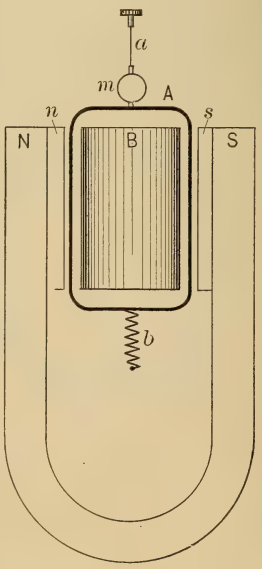


FIG. 6

in practice; it consists in their extraordinary susceptibility to external magnetic influences such as arise from moving masses of iron and magnetic material in their vicinity. Numerous

efforts have been made to overcome this difficulty, by completely surrounding the instrument with a thick shield or case, also of iron, designed with a view to intercepting the disturbing magnetic lines of force and thus preventing them from reaching the suspended system. A shield of this description constitutes a feature in the construction of the Thomson marine galvanometer described above. The remedy is, however, only partially successful, and frequently introduces further trouble by accidental magnetisation of the case itself. The real remedy, and one which is now being almost universally adopted, is that of reversing the fixed and movable elements of the galvanometer, thereby converting it into an instrument of the so-called d'Arsonval type, named after its inventor. In these instruments a light rectangular coil of very fine wire, *A*, Fig. 6, is suspended between the poles of a powerful steel horse-shoe magnet, *NS*, the magnetic circuit being rendered as complete as possible by the addition of semi-circular shaped cheeks or pole-pieces *ns*, which practically surround the coil, and a laminated cylinder of soft iron, *B*, which is rigidly supported inside the coil and serves to complete the magnetic circuit with the exception of the two air-spaces left for the free movement of the coil.

The current to be measured is led into and out of the coil by way of the suspensions, which consist of a fine phosphor-bronze ribbon, *a*, at the top, and a loosely coiled spiral of the same material, *b*, at the lower end. The coil *A* is wound on a light rectangular frame of ivory or aluminium; if the latter, it must be divided at one point by an insulating piece, or air-gap, or the induced currents set up in the frame itself, will make its movements very slow. This fact is made use of in what are known as "dead-beat" instruments, in which the metal frame forms a complete electric circuit, or, in default, a few turns of the coil itself are short-circuited upon themselves. The motion of the coil under the influence of a current passing through it, is thus rendered very deliberate, and is automatically checked on reaching the zero point of the scale.

As in the Thomson form of reflecting galvanometer, the mirror *m* is attached to the suspended system at a point just above the coil, and the usual lamp and scale provide a ready means of reading the deflections.

There are several excellent patterns of this instrument on the market and it has, in fact, been brought to such a pitch of perfection that it now rivals the Thomson instrument in the field of sensitiveness.

Sullivan's universal galvanometer is a very excellent pattern of this type, and, as its name implies, is adapted for a multiplicity of uses, either on sea or land. The permanent magnet is circular, and is arranged horizontally on a substantial base, being provided with a gap for the reception of the coil. The latter, with its soft iron centre, is mounted in a frame which fits into convenient slides in the body of the instrument, providing a ready means of inspection and renewal, and making the magnet and body of the apparatus available for the various purposes for which it is designed, by simply taking out one frame and substituting another; in fact most modern types of d'Arsonval galvanometer have their coils arranged on this principle.

For stationary use on land, the suspensions are similar to those described in connection with Fig. 6, the upper ribbon being attached to a tension screw. For use at sea, however, it is obvious that the suspension must be absolute, whatever the position of the instrument as a whole, and the lower ribbon is consequently straight, attached to, and kept taut by, an adjustable spring. Camel-hair brushes, fitted to the frame, and bearing on the suspensions, form an admirable damping device, and it is claimed that, with this instrument, it is possible to obtain reliable readings on board a torpedo boat going full speed ahead,—no mean gauge of its capabilities as the experienced reader may well imagine.

Reverting to the original type of instrument, in which the magnets them-

selves constitute the moving element, we come now to a type which is not often met with in every-day practice, namely, the ballistic galvanometer. In dealing with electric currents of very brief duration, such as the electrostatic charges in a condenser, or a long length of submarine cable, we have to cope with a condition of things for which the ordinary forms of instrument are totally unfitted, in that they are incapable of responding in so brief an interval of time, except by an irresponsible swing of the moving system, which takes place too rapidly to be of any assistance as a record. To meet this difficulty, the

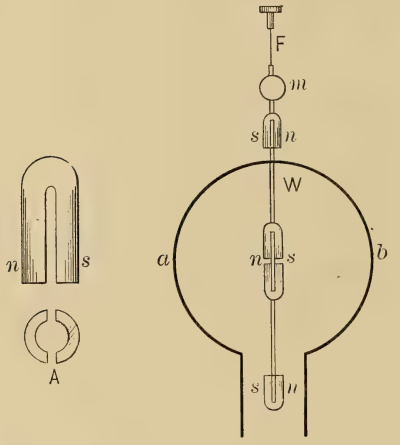


FIG 7

ballistic galvanometer was designed.

The magnets, instead of being straight, like the watch-spring variety in Lord Kelvin's instrument, are made thimble-shaped as at *A*, Fig. 7, which represents an enlarged elevation and section of one of the magnets. They are of steel, hollow in the centre as shown and provided with a saw-cut along the greater part of their length, which converts them into miniature horse-shoe magnets with semi-cylindric limbs. The object of this construction is to provide for as little air resistance as possible during the movement of the suspended system, which, as it does not take place until the current causing it has practically ceased, is a very necessary provision. Four of these magnets, equal in size and degree of magnetisation, are mounted, as shown, on a vertical aluminium wire, *W*, so as to form an astatic system, two of them being together at the centre of the coil *a b*, and the remaining two at short distances apart, but in close proximity to the edges of the coil. The mirror *m* is fixed in its usual position, just above the coil, and the system is suspended, as in the ordinary type of instrument, by the fibre *F*. Transient electric currents, such as those resulting from electro-magnetic induction, are readily measured by the aid of this instrument, which depends for its action purely upon the inertia imparted to the magnets *n s*, during the extremely brief duration of such currents.

We have already discussed the "dead-beat" principle as applied to galvanometers of the d'Arsonval pattern, and it may interest the reader to learn that this convenient method of control has also been applied by Lord Kelvin to the ordinary mirror galvanometer, though the method of obtaining that quality is rather different. The mirror, with its attached watch-spring magnets, is suspended by a very short fibre, inside a cylindrical tube slightly larger in diameter. there being just sufficient clearance to allow the mirror to swing freely. The inside of this tube is threaded from both ends, to receive two small screwed bezels, fitted with circular glass discs; when these are screwed into position the mirror is enclosed in a practically air-tight chamber, and is therefore put to the necessity of displacing a certain small volume of air in its every movement. The friction thus set up is just sufficient to exercise the necessary damping effect, and the suspended system, on being subjected to the current flowing round an encircling coil, swings slowly round to the limit of its deflection, and back again to the zero position, without any further oscillation about that point as in the ordinary form. Additional damping effects are sometimes secured by filling the closed chamber with paraffine oil, which slightly reduces the sensitiveness of the device.

A long-range, or, as it is sometimes called, cosine galvanometer, was the

independent invention of Dr. E. Obach, and Professor John Trowbridge, who made the discovery unknown to each other, in 1871.

In construction, it somewhat resembles the tangent galvanometer, already described, with the exception that the coil or ring is capable of rotation round a horizontal axis or diameter, its angle of inclination being recorded upon a quadrant scale. On due consideration it will be seen that the magnetic influence of the current flowing round the coil, upon the needle, can be varied from a maximum when the coil is vertical, to a minimum, or zero, effect when the coil is horizontal, and therefore in a plane with the needle.

The fundamental principle of this galvanometer is based upon the law that the strengths of the currents flowing round the coil, are directly proportional to the tangents of the angles of deflection of the needle, multiplied by the corresponding secants of the angles of inclination of the ring.

A further detail in its construction affects a point which, at first glance, is apt to be overlooked, viz., the tendency of the needle itself to dip with the corresponding inclination of the coil. This is prevented by mounting the needle, of bi-conical form, on a long, light, vertical axis, fitted at its lower extremity with a small cylindrical metal weight, which, whilst adding very slightly to the inertia of the system, suffices to absolutely prevent any actual movement other than in a horizontal plane. A light vane attached to the axis, and playing in a shallow cylindrical chamber, provides the necessary damping effect.

This completes a brief category of the principal types of galvanometer in use up to the present day, with the general outlines of their various constructional principles.

THE STEAM SHOVEL IN MINING

ITS USE IN THE LAKE SUPERIOR IRON ORE DISTRICTS, IN THE UNITED STATES

By A. W. Robinson, M. A. Soc. C. E.

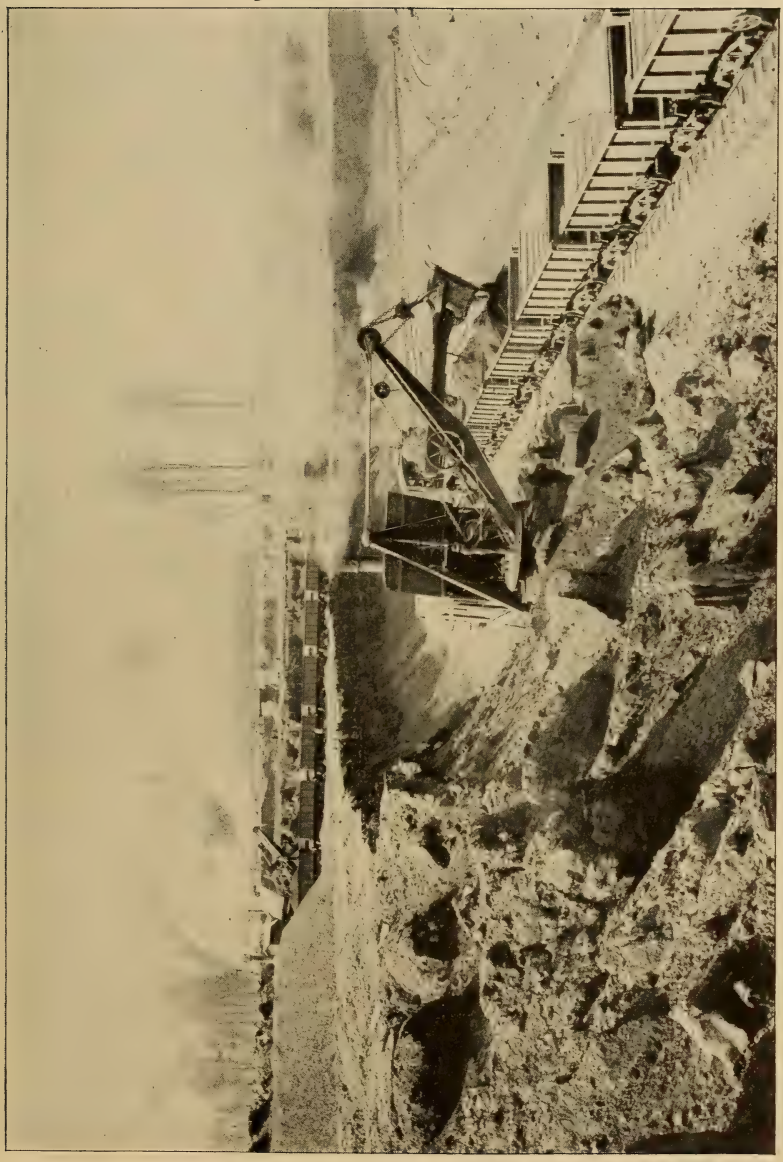
THE modern steam shovel is the product of evolution,—a growth from a crude beginning to a high development that seems nearly perfect. Yet this perfection is only comparative, and who shall say what future development will bring forth? Like the locomotive, the steam shovel has grown in response to the constant demands for more power, more strength, more capacity, and greater economy. Like the locomotive, too, it is limited in its growth by the restrictions imposed by having to run on a standard-gauge track of 4 feet 8½ inches.

Ten years ago a locomotive weighing fifty tons, with 17 × 24-inch cylinders, was considered a good size. Now the weight and steaming capacity have doubled, and for regular freight duty the weight is 120 tons, and the cylinders measure 20 × 26 inches or more. The growth in the steam shovel is even more remarkable. Ten years ago the ordinary railway and mining shovel which was considered as "standard" weighed thirty-five tons and carried a bucket of 1½ cubic yards capacity. Now such a shovel is not considered worth operating, and we find a machine standing on the same track and handled by the same crew that weighs ninety tons and carries a dipper of four cubic yards capacity, and even this has in some cases been exceeded.

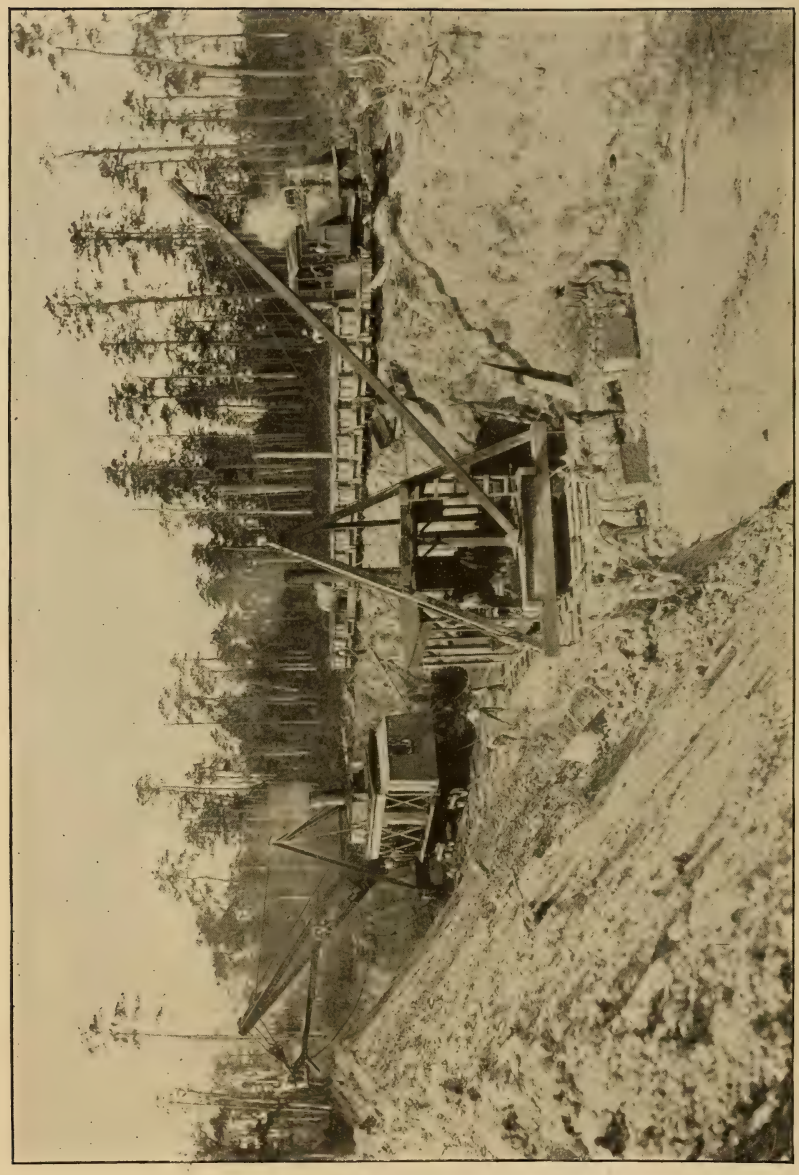
These large shovels were at first thought to be too heavy and too difficult to handle, but, as a matter of fact, they are easier to manipulate than the earlier, small shovels. The movements of the shovel are rapid and complex, and entail much labour on the operator. In the earlier steam shovels all these movements were controlled by operating levers worked by hand, while in the large modern shovels these movements are performed by steam-actuated levers, the operator being thus the brain, as it were, of the machine, and performing little or no manual labour.

The speed of working under ordinary conditions is four dipper loads per min-

WORKING GOLD GRAVEL IN CALIFORNIA WITH A STEAM SHOVEL AND A ROBINS BELT CONVEYOR



A STEAM SHOVEL WORKING IN FROZEN ORE IN THE MAHONING MINE, LAKE SUPERIOR



PHOSPHATE MINING. THE SHOVEL IS HERE SHOWN EXCAVATING OVER-BURDEN. NEGROES ARE DIGGING OUT THE ROCK WHICH IS LIFTED INTO CARS BY SPECIAL HOISTS

ute. Each load requires eight separate movements on the part of the two operators, namely, hoisting, feeding or thrusting, swinging out, dumping, return swinging, dropping back, pedal braking on dipper handle, lowering brake on hoisting. This makes thirty-two operating motions per minute, and, in addition, the constant control of speed by the throttle. The importance, therefore, of making these motions easy and responsive to the will of the operator is apparent, and to this ease and responsiveness may be credited much of the effective work now accomplished. The importance of the place occupied by this modern engine of civilisation may be understood by the consideration of a few figures. An average day's work of a good shovel is about 2400 cubic yards, or 3600 tons. An able-bodied labouring man can pick and shovel about 3 cubic yards of ordinary material per day, or 4½ tons. A second man could shovel this to a level of not over 8 feet high, and a third man would be needed to cover the height lifted by the shovel, the men working in relays. In other words, three men could pick, dig, and lift three cubic yards of ordinary firm material per day. The shovel, therefore, represents the labour of 2400 men. There are probably 2000 shovels in active service in the United States and Canada, which are thus doing the work of 4,800,000 men. Indeed, it can be said that they are doing work which could not be done by any number of men, the material being oftentimes so hard and the conditions so difficult.

As the function of the steam shovel is that of excavation, it is not astonishing that it should find a large field in mining, the principal applications being in iron, coal, gold, and phosphate mining. Iron ore comes first in importance, and the development of steam shovel work in this direction merits more than a passing description. The first steam shovels for iron mining were borrowed from the railways and were used for stripping and uncovering the bodies of ore that lay near the surface in the Lake Superior district, in the United States. It was then but a step further to put the shovel into the ore bed itself and load cars for shipment. The mine operators

A 98-TON STEAM SHOVEL BUILT BY THE VULCAN IRON WORKS CO., TOLEDO, OHIO, U. S. A.

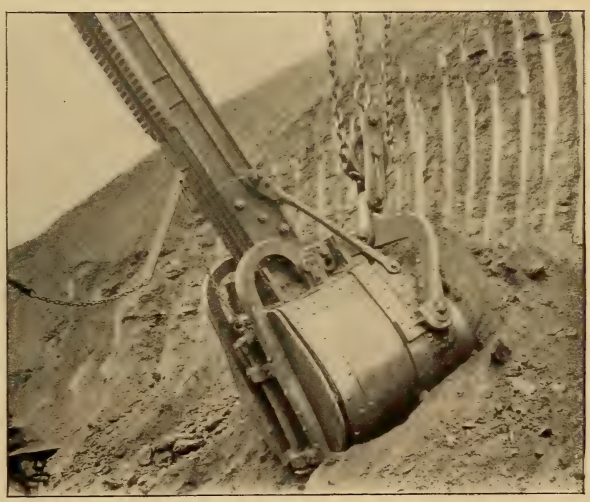
VIEWS OF STEAM SHOVEL WORK AT THE MAHONING MINE

were quick to see the possibilities of this method, and put on a number of shovels, both for stripping and mining. These first shovels were generally of the railway type of a few years ago, and proved unequal to the more severe work of mining. Breakdowns were frequent, and a much heavier and stronger type of machine was developed, which proved much more serviceable and durable. One of the earliest of these heavy shovels was designed by the writer for the Mahoning mine in 1893. The output of this mine, like that of all the northern mines, is shipped to Lake Superior by rail, and is there loaded into steamships for shipment into Lake Erie ports and Pennsylvania furnaces. Two of these machines were put in service with the idea of serving the steamships direct from the mines without the intervention of storage or stock piles. In other words, the storehouse from which shipments were made was the undisturbed body of ore in its natural bed. Service like this called for systematic management to deliver cargoes to the ship as required without delay, and also for a shovel that could be depended on absolutely for large output throughout the season. These shovels are still in service, after having handled about 2,000,000 tons of ore each.

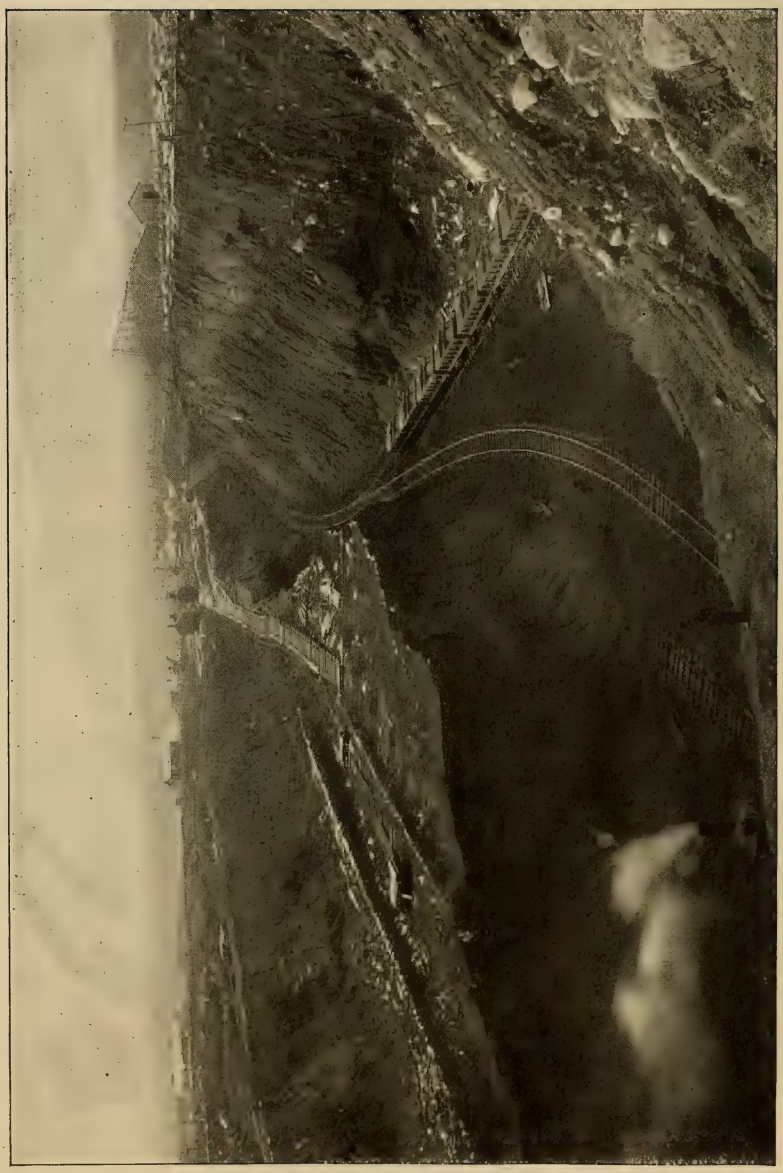
It requires a very favourably situated mine to be handled in this way, and in order to equalise supply and demand vast stock-piles are accumulated. Especially is this the case with underground workings. These continue to work all winter when stocks accumulate owing to the close of navigation. These winter-made stock-piles are generally frozen solid, due to the gradual addition of layer after layer of ore, often with snow in between, and in spring, when shipment begins, they present a very difficult face for the shovel to attack. Such, however, is the great strength and power of the heavy shovels now used that they are able to tear up this frozen mass of iron ore and load it on cars with but little, if any, aid from blasting.

Thus it appears that there are three great divisions of work in iron mining as practiced on the Lake Superior ranges which are almost wholly performed by steam shovels. These are:—(1) stripping or uncovering the beds of ore; (2) digging the ore itself in "open-pit" mining and loading it on cars; and (3) loading cars from stock-piles. Thus the steam shovel has become a most important factor in iron ore production by contributing its powerful aid in uncovering and handling millions of tons in a direct and cheap manner. Indeed, it is safe to say that without the use of these machines the great development of the United States iron ranges of the north would have been impossible.

The liberality of Nature in providing such vast bodies of ore and the marvellous efficiency of the steam shovel in unearthing and loading it for shipment have, together, been instrumental in bringing about the advanced position of the steel industry of the United States which we now see. The whole world is looking on with wonder and sending

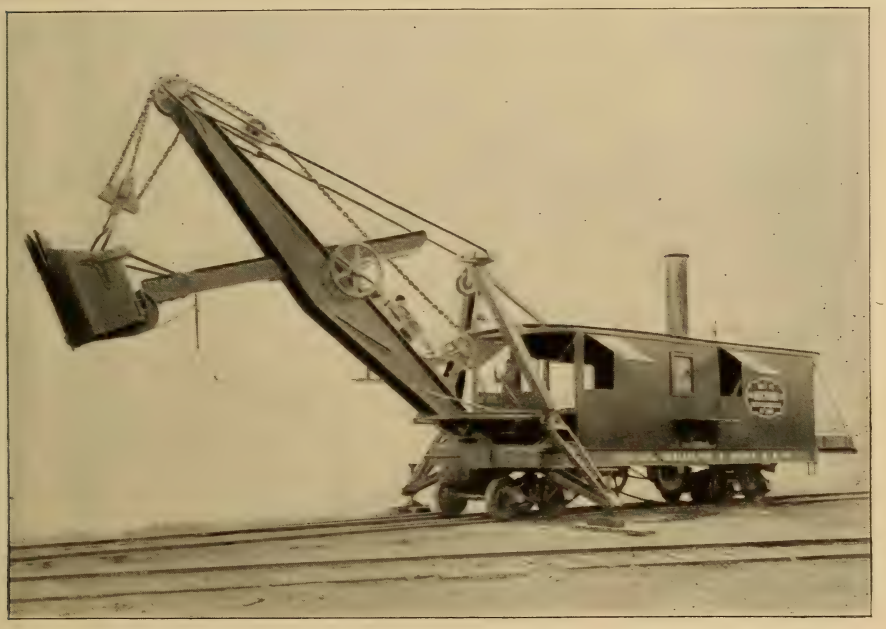


THE DIPPER OF A STEAM SHOVEL



THE BIWABIC IRON MINE ON THE MESABI RANGE IN MINNESOTA, U. S. A. TYPICAL STEAM SHOVEL TERRITORY

their experts to see how it is done. Systematic economy on a large scale is manifest at every step of the process, from the ore in the mine to the finished steel. The first cost of getting the ore is but a trifle. A good shovel will dig the ore and load it on cars for about one cent a ton, or even less. The remainder of the cost is made up of royalties and transportation charges. In transportation the cost is kept low by handling large quantities on an organised system.

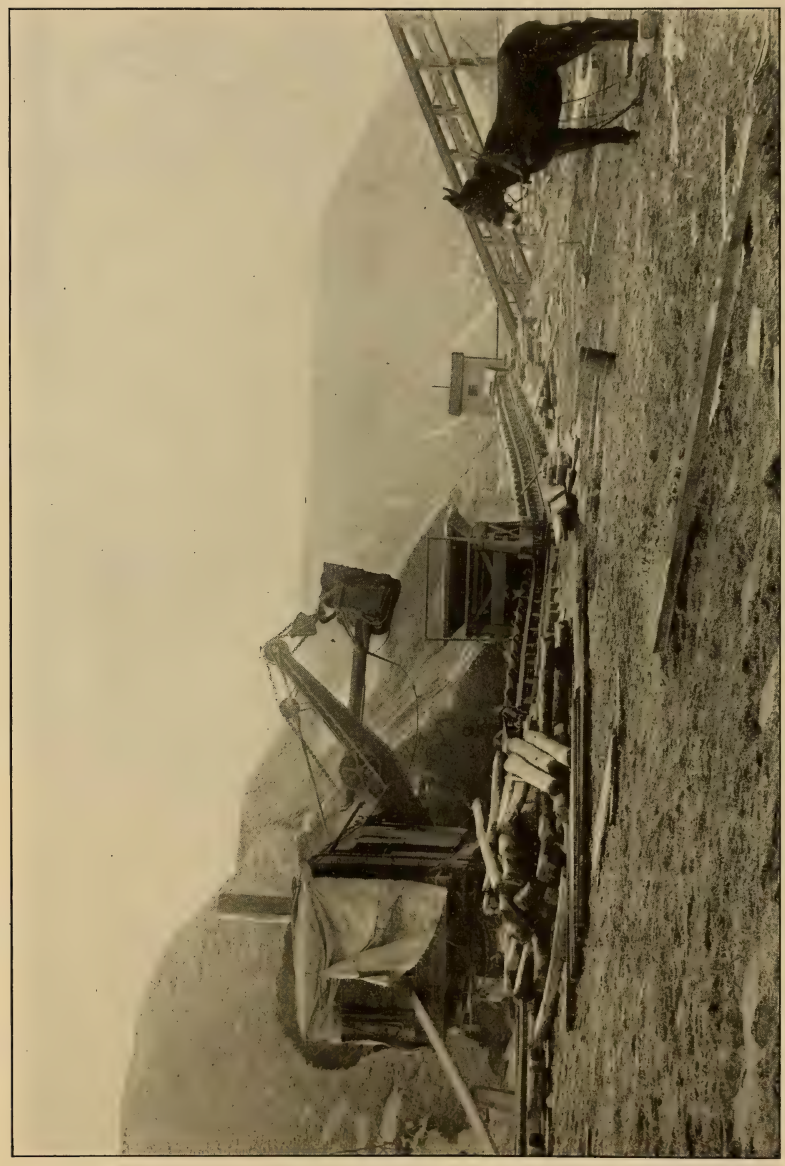


ONE OF THE SHOVELS MADE BY THE BUCYRUS COMPANY OF SOUTH MILWAUKEE, WIS.

Compare British or Swedish methods with the Lake Superior methods, and one reason for American cheap steel will be at once seen. In the former the railway cars are of small capacity, carrying ore to be shipped in a miscellaneous lot of vessels with all shapes and sizes of receiving hatches, and a variety of loading appliances, most of which are slow. In the latter we see solid trains of cars holding 100,000 pounds each, and a fleet of vessels with their cargo hatches built on the interchangeable system as to size and distance apart, and the loading and unloading devices made to suit them. The vessels are very long, and the hatches are uniformly 12 feet apart. The ore chutes at the receiving dock and the multiple hoists at the discharging dock are also 12 feet apart, so that when a vessel with eight or ten hatches comes alongside they all load or discharge simultaneously. In this way a cargo of several thousand tons is received or discharged in a few hours.

During the season of 1900 the shipments of Lake Superior ore aggregated 19,059,393 tons from 106 mines on the five great iron ranges of the north, the Mesaba, Vermilion, Gogebic, Marquette, and Menominee. These figures convey some idea of the magnitude of this industry.

Turning now to the use of shovels in coal mining, their principal use is in stripping coal deposits that lie near enough to the surface to be worked in this way. The advantage of open-pit coal mining is that the entire bed can be taken out, whereas in underground mining much coal is left as pillars, and cost is incurred in timbering. Many



THE STEAM SHOVEL IN THE PENNSYLVANIA COAL REGIONS, LOADING CULM ONTO A BELT CONVEYOR MADE BY THE ROBINS CONVEYING BELT CO., NEW YORK

mines in Pennsylvania are worked in this way. Shovels are also used in handling coal in bulk from stock-piles.

In gold mining, steam shovels are used only to a limited extent, but in certain localities where conditions are favourable to their use good results are obtained. Many of the alluvial deposits of placer gold are worked by floating dredges, and the gold is saved by sluice boxes placed on the dredge. There are vast areas of dry gold-bearing gravel lying above water level, and these have for that reason been left alone. It is impossible to work these deposits without water to wash the gravel. The steam shovel offers a solution of the difficulty by excavating the gravel and delivering it either into a sluice box supplied with water by pumping, or into cars to be transported to the water at a lower level.

In phosphate mining, shovels have been successfully used both for stripping and mining. The principal phosphate deposits of the United States are those of South Carolina and Florida. In both localities the beds of phosphate occur near the sea level, extending in some places out under the water where the deposits are worked by dredging. On land they are covered by from 10 to 30 feet of earth, which must be stripped off, and in this work the shovels have performed excellent service.

THE TESTING OF STRUCTURAL MATERIALS

A FACTOR IN INDUSTRIAL DEVELOPMENT

By Paul Kreuzpointner

WHOEVER has had opportunity to observe the development of the iron and steel industries and kindred branches during the last twenty-five years can hardly have failed to note the various factors which, collectively, have contributed towards the gratifying results of to-day.

A goodly share of national prosperity is due to lowered costs of railway transportation, and in securing these, much has depended upon the attaining of those excellent qualities of structural materials of all kinds which enabled constructing engineers to employ a minimum of material with a maximum of safety. This reduced the cost of construction and increased the safe efficiency of materials of construction so that speed and hauling power on railways could be brought up to the point where they now are.

To bring structural materials, notably structural steel, up to the present standard of efficiency and economic value was a slow process of evolution, and having had an excellent opportunity to take an active part in carrying out the details of the transitory period from iron to steel, the writer can say that the younger generation of engineers and iron and steel makers have no conception of the trials and difficulties, vexations, and anxieties which were daily experienced by the engineer and steel maker twenty years ago, when steel fought for recognition as an equal and superior to iron; when there were no accumulated data to fall back upon to say what steel could do in place of iron; when knowledge of the properties and qualities of structural iron and steel was sadly defective, and the engineer and manufacturer often did not know, and could not know, what they wanted and what they ought to do; when, for a time at least, the boiler maker, through his prejudice against steel, his timidity and want of knowledge of how to use steel, dictated to the steel maker what grade of steel to make;

when good judgment and common sense and an intuitive insight into qualities and properties of metals were at a premium, and when that degree of uniformity which now prevails in steel during given periods and between various makers was an unknown quantity.

The writer can recall the time when there was a difference of 19 per cent. in the quality of a given grade of steel, as measured by tensile tests, from, say, a dozen manufacturers, and he was able to tell a maker's product by the finish and colour of the steel, while now there is hardly any difference. Those were trying times, indeed, for both the producer and consumer, relieved later by tests and standard specifications to control the quality or qualities of a given structural metal for a given purpose.

Like structural steel, so testing and systems of testing went through a period of development and transition; but in the end testing and analysing proved, and still proves, in ever-increasing ratio, an economically very important, albeit silent, factor in industrial development by being an indispensable arbiter in deciding as to the safe and economic value of the immense quantities of structural materials used at the present day.

When so-called "mysterious" failures began to make their appearance with the new metal and the faith of the friends and defenders of steel was strained beyond the limit of elasticity, the then new system of testing gave assurance to the timid and hesitating engineer, and to the manufacturer it proved to be a beacon light to show him the safe course for his metallurgical craft. To the mill men the testing engineer assumed the function of an educator and guide as to the manner and method of production and treatment of the metal. How else could we have attained such remarkable results as the production of bronze propellers, with a strength of from 70,000 to 73,000 pounds per square inch and an elongation of from 29 to 30 per cent. in 8 inches, than by the guidance of the testing machine and chemical analyses, leading, step by step, to the present high degree of perfection!

What a wonderful transition, with the help of the testing machine and other now well-known means of examining the physical qualities of metals, from the first irregular results of tentative metallurgical efforts of mass production to the present uniformity, solidity and reliability of product under the intelligent guidance of a system and methods of testing founded and based upon a wealth of experience, accumulated data and scientific investigations of the properties of metals!

But the advent of testing as a regulator of product and an indicator of the skill of men in the shops in working iron and steel was not hailed with acclaim and brass bands. Many were the maledictions heaped upon the head of the unlucky expert who declared a given material suitable to be worked if the workmen were only willing to learn how to do it, and the causes producing differences of opinion between producer and consumer were sometimes more amusing than aggravating.

Thus the writer remembers a case where the results of tests were questioned, and it turned out that not only had one man used a test section of different dimensions than the other, but he had also prepared the test section by grinding a semicircular groove into the test piece by means of a dry emery wheel, in utter oblivion of the effects upon the metal under test of the rough edges of the section and of the change in the quality of the metal due to the blue heat to which it was subjected during the emery wheel grinding.

But it must not be imagined that testing originated with the growing necessity of ascertaining the commercial value of the masses of structural material produced upon an ever-increasing scale. As early as the latter part of the eighteenth century the Frenchman Souflat, who died in 1781, had made tests of the strength of iron. So had the Englishmen Reynolds and Brahma about the same time. Von Siekingen, a Swede, published results of tests of iron in 1782. Eytelwein published the results of his experiments of the strength of iron in 1808. So did Tredgold in 1810 and Bandelet in 1814. "The Strength and

Stress of Timber" was published by Barlow in 1817, while "Experiments on the Strength of Materials" was published by Prennie in 1818.

Systematic and scientific experiments on the strength of wrought iron were carried on by the Frenchman Dulean in 1820, and Tredgold published his "Practical Essay on the Strength of Cast Iron and Other Metals" in 1823. Seguin's work on wire bridges appeared in 1824, while Sagerhjelm's valuable experiments on the density, uniformity, elasticity, malleability, and strength of wrought iron were given to the world in 1824. As early as 1807 Thomas Young advocated the adoption of a modulus of elasticity, while Karsten in 1826 established the strength of iron and various sections and diameters. Tredgold established the proportion of elasticity to strength to be 0.3. According to Sagerhjelm, it was between 0.360 and 0.438, showing that rather accurate work of testing was done in those early days. Tredgold ascertained that permanent set took place in cast iron at an elongation of 1-1264th of its length with a load of 15,300 pounds per square inch.

Pictet made extended series of compression tests, and found that a brittle body (nature of the body is not stated) was shortened 0.000022 of its original length under a load of 260 pounds, and sustained a permanent reduction of 0.0000023 of its length.

Tredgold also made experiments on the influence of heat on the strength of iron, and claimed that with every degree of Fahrenheit it diminished 0.0003289. Prinsep established in 1829 the fact that the dimensions of cast iron could be increased permanently by heating the iron.

These data, showing an early interest by scientific men in the physical properties of iron, are part of the records given in "Beck's Geschichte des Eisens." Woehler, whose tests on the fatigue of metals, which he began in 1857, were carried on by Spangenberg and are continued to-day by Martens, is said to be the father of our modern small testing, though Kirkaldy, Fairbairn, and Styffe did a good deal to popularise commercial testing. Woehler was the first to set up the formula, —strength plus contraction of area must be 100, with an acceptable minimum of 95 as a measure of quality. This rule, however, never had many defenders, since it was found that contraction of area followed no law.

In more modern times Bauschinger's classic work on the properties of metals under various conditions has been a most valuable guide to the engineer and investigator, while Martens, his talented friend and scholar, Barba, Osmond, Chatelier, Kick, and others have ably helped to broaden our knowledge of applied metallurgy.

The economic value of methods of testing materials of construction and the intimate relation which a thorough system of testing bears to industrial development and transportation are attested to by the existence of an international association for testing materials of construction and the increasing attention paid to the science of testing by technical colleges and universities.

But while wonderful progress has been made in the art of producing structural materials of a high degree of uniformity, quality, and reliability, it would be a serious mistake to be content with present achievements and sacrifice the teachings of science and of expensively acquired experience to purely commercial considerations. With the decrease in quantity and quality of mineral resources and timber, the demand for the application of scientific methods to all details of production will be largely intensified as compared with present conditions. This will arise also from the necessity of an increased economic value of the products of all industries to the consumer, who will be compelled, by reasons of economic changes in our mode of living, to demand more value for the same, or even a lower, price than he pays now.

This, in turn, will mean a still more careful study of those means and methods whereby the properties and qualities of metals are ascertained, defined, and properly regulated in their daily application for practical uses. From the ex-

perience accumulated thus far it is safe to say that the study of the structure of steel and alloys under various physical and chemical conditions will occupy the attention of the best metallurgical talents, and the melting, heating, and annealing of metals by the aid of pyrometers will attain a degree of perfection unknown at the present time. It is a matter of satisfaction to know that the technical schools have already laid a good foundation for the study of the properties of materials of construction and the best methods of their practical application for daily use. But with all due respect for, and appreciation of, the work that has been done and is being done by these schools, the fact remains that their usefulness in that branch of learning which deals with applied metallurgy and materials of construction will be impaired and unsatisfactory as long as they are not in touch with the daily and hourly experiences acquired in the use and production of metals, especially steel. In the daily application of the knowledge of physical metallurgy, judgment must ever form a large part of the stock in trade of the engineer and steel maker.

Valuable and indispensable as the chemist, the microscope, and the testing machine are, and will be in the future, metals exhibit certain phenomena and characteristics which can never be reduced to an expressible form by instruments and mechanical means of any kind. This peculiarity of metals, notably of steel, to defy all attempts to be squeezed into the strait-jacket of rules and formulas and transmissible language, is what causes the steel maker so often to have little faith in school metallurgy and text-books. He and the one who daily tests commercial quantities of steel and sees that same steel come back years after, worn out and destroyed, know only too well what an important part good judgment plays in the proper estimation of the characteristics of steel and its behaviour, and that judgment can be formed only in daily contact with the commercial product in mill and shop. This is the missing link in that branch of engineering education which deals with applied physical metallurgy. How to make the study of the physical properties and qualities of metals as complete and practical as possible by supplying that missing link, namely, the steel maker's and tester's judgment and knowledge of the influences of variable factors – that is the problem to be solved, if it can be solved.

Prof. V. C. Alderson, Dean of the Armour Institute of Technology, of Chicago, in a recent pamphlet on "German Technical Schools," in which he described the testing department at the Zürich Polytechnicum, very properly remarked that there is to-day no greater opportunity open to high-grade technical schools than that afforded by education in this direction. Tests conducted in properly managed departments of such schools, and carried out on a commercial scale, would be of value to builders, architects, and engineers everywhere.

Judging from twenty years or more of experience in testing very large quantities of commercial product every year for its physical qualities, made by all kinds of processes and methods which have been in vogue during that trying period of the metal industry, the writer believes that such work would not only raise technical schools to a higher level of practical usefulness to their students, but it would largely bridge the gulf between the consumer and producer, that is, between the steel maker and the engineer, which now so often exists by reason of the missing link,—that ability to judge of the quality of steel, as an aid and supplement to the mechanically and chemically performed test, by the appearance of a tensile fracture, a nicked fracture, a fracture without nick, a nick-bend, a bend without nick, the creased or smooth appearance of the surface of a test piece after tensile test, the degree of resistance felt by the investigator when testing a piece of steel in the vise or with a sledge, whereby one piece of steel may be found "short" while another similar piece is not short, though both may have the same tensile strength; to say with approximate correctness whether a given product was bad from beginning or was damaged by overheat-

ing, and many other phenomena in physical metallurgy which are not found in books, which there is no language to describe, and which cannot be demonstrated by formulæ, but which are, nevertheless, tangible factors in determining the wear and tear of a material. They are not mysteries, since their presence and influence are seen and felt every day by those who have the opportunity of handling large masses of steel and other metals.

The value of such purely practical knowledge and judgment is greatly increased if one has the priceless opportunity to test and examine the new material and then test and examine the same material after it has been worn out slowly, or destroyed violently, by forces over which the engineer has no control, and which are beyond his, as well as the manufacturer's, calculations.

It must be admitted that in a four years' course in a college, besides all other studies, the student could, even under the most favourable circumstances and conditions, acquire but an inkling of that knowledge which has here been called the missing link; but the writer feels sure that even that little would help many a time to a better understanding between engineer and manufacturer, when the former tries to squeeze all his ideas of physical qualities into the straitjacket of unyielding formulæ, while the latter declares this to be theoretical over-refinement, knowing that such attempts are like trying to force a rubber ball into a box too small for its size; when the cover is forced down, the side breaks out, and if the side is squeezed back, the bottom goes through. Prof. Alderson's idea could be made still more valuable if college students could be sent out by large consumers as material inspectors for a few months at a time, thus teaching them to appreciate the difficulties the maker has to contend with, modifying their views and theoretical knowledge in one direction, while enlarging and strengthening them in another.

This, in the course of time, would develop a degree of mutual understanding and appreciation of one another's position between engineers and manufacturers which would work to material advantage all around.

Current Topics

THE introduction of superheated steam into engines largely influences the expansion of the heated parts. Mr. R. Lenke, in an already much-quoted paper before the Institution of Mechanical Engineers, dealing with the use of highly superheated steam, tells that engines always gave great trouble when the distribution of metal in the cylinders was not uniform, as parts with more metal expanded most, and thus forced the cylinder walls out of shape. When using liners in the cylinders, they were squeezed in at the ends, decreasing the diameter, and jamming the piston body if sufficient clearance was not provided. With steam jackets heated with steam of 500° F., the lubrication ceased as the cylinder walls became too much heated; consequently it was found necessary to do away with jackets, or, if jackets were already provided, not to pass steam through them. Pistons constructed on the Ramsbottom type always worked satisfactorily, except in the case of pistons fitted with steel springs, when they were in contact with highly superheated steam. Any kind of gunmetal gets brittle after a very short time; therefore valves, seats, and all parts in direct contact with superheated steam, must be made of cast iron or other suitable mixture. Copper also loses about 40 per cent. of its strength at the above mentioned temperature, so that copper bends in pipes are not practicable. The best material for piping has proved to be wrought iron and steel, each pipe being as long as possible, so as to have the least number of flanges. For long, straight pipe connections, provision must be made to meet the expansion, which is, at 700° F., 0.0037 of the length, so that, for example, 100 feet of pipe extends 0.37 of a foot, or nearly 4½ inches.

GLANDS and stuffing boxes at first frightened users of superheated steam, and engines were therefore constructed single-acting to avoid the use of glands; but no serious difficulties have arisen on that account. It is advisable to place the stuffing box as far as possible from the cylinder end to keep it well away from the hottest parts, and to allow of as much radiation as possible. Sufficient clearance in the neck bush should be made to allow for the expansion of the piston rod, and no metal with a melting temperature below that of the steam should be used. Valves and valve gears are influenced in the same way by super-

heated steam. Valves containing many ribs or different thicknesses of metal (in section), such as plain slide-valves or Corliss valves of the usual construction, are not suitable for high temperatures. A Corliss valve of medium size will stand 480° to 500° F., but no more, and the latter temperature very seldom. The smaller the plain slide-valves are, the higher temperature they will stand. Large slide valves will hardly stand even slightly superheated steam if no provision is made for forced lubrication of the valve face. Piston-valves have proved to be most suitable for the highest temperature, owing to their uniform distribution of metal, but even with this sort of valve certain experience is necessary to get them in good working order. As it is impossible to rely on tightness of piston valves, they must be made as small in diameter as possible. It may be stated here that superheated steam can travel at 30 to 40 per cent. higher speed through steam ports than saturated steam, and this fact has to be considered during construction.

One important drawback to the use of dust fuel has been stated to be that, on account of the risk of spontaneous combustion on the one hand, and of its tendency to absorb moisture from the air on the other, the fuel cannot be stored in a finely-ground state with safety and efficiency. In one plant, of which particulars were recently given and which uses such fuel under a 250 H. P. boiler, a coal grinding machine forms an important part of the outfit, reducing the coal to a fine dust which is fed into the furnace by a jet of compressed air. The air and coal dust issue from the air nozzle well mixed and burn very much like a stream of gas, the best combustion results being obtained when the coal is ground so fine that 90 per cent. will pass through a 150-mesh sieve. The crushing and grinding machinery is of such capacity that it can supply the dust as rapidly as it is wanted and only a trifling quantity is stored. Tests are said to have shown that less than 1 per cent. of the power produced by the coal burned under the boiler is required for the pulverising.

Almost from the earliest date when acetylene became practically available for producing artificial light, the problem of using the gas for driving explosion engines has been under consideration. According to *The Engineer*, of London, the various researches published by Berthelot, Vieille, and Le Chatelier on the explosive character of mixtures of acetylene and air, seem, at first, to have created a feeling that the gas could hardly be safely employed as a motive power; the violence of the explosions is so great, the speed of propagation of the wave so high, and the point of inflammation so low that many persons felt it would be dangerous to attempt to drive an ordinary engine in the manner indicated. The liability to dissociation exhibited by acetylene when the gas is raised to any pressure exceeding that of two atmospheres or thereabouts also introduced another difficulty, as this kind of decomposition would give rise to the formation of free carbon, which would block up the ports and valves of the machine. However, many investigators took up the problem in spite of its unpromising appearance, and published in different journals a large number of experiments, chiefly on the theoretical aspect of the question, and on the behaviour of mixtures of acetylene with a chemically large excess of air when exploded in tubes of various sizes.

On endeavouring to pass from the region of experiment, and trying to ascertain what has actually been done in the way of using acetylene as a motive power in every-day work, all the published information is found to be extremely vague. The firm of Moritz Hille, of Dresden-Löbtau, Germany, was, according to one authority, the first to build special engines for the new gas. These are almost identical in construction with ordinary gas engines, but

have changeable cylinders and cooling jackets. The cylinders are said to be made of specially hard metal. The engines are built in various sizes up to 20 horse-power, and are stated to consume between 180 and 220 litres of acetylene per horse-power-hour. The cost of a 3 horse-power engine is £100; of a 10 horse-power, £210; of a 20 horse-power engine, £360. More recently the Allgemeine Carbid und Acetylen Gesellschaft, of Berlin, has been making similar engines in sizes ranging from one-half to 6 horse-power, both vertical and horizontal. According to Vogel, several of the central acetylene installations in German villages are provided with gas engines which are in regular use to raise the water needed by the generators. A fair number of the large buildings which are lighted by acetylene in the less populous parts of the Continent, such as hotels and factories, have also installed gas engines to pump up their water supply, to generate small quantities of power, or to perform other domestic duties. The gas consumption is returned at 160 litres per German horse-power-hour in engines of from 4 to 8 horse power. At Ellerbeck, and one or two other towns in Germany, the owners of the central acetylene installations offer to supply gas at a specially reduced rate for motive purposes, and we may, therefore, imagine that there is a demand for power; but again no information has been given as to the results obtained in practice. The well-known firm at Deutz report that many customers have experimented successfully with acetylene in their ordinary engines. They find that the gas must be quite dry, and that the consumption averages from 250 to 300 litres per horse-power-hour.

When it comes to using acetylene for motive power for vehicles, there are two ways open. The gas can either be generated on board in the usual fashion from calcium carbide, or it may be stored in cylinders after compression into porous matter in the presence or absence of acetone. This latter method of employing the gas has been legalised in Great Britain after a number of experiments carried out last spring at Woolwich Arsenal, a special exception to the order prohibiting compression having been published. Compressed acetylene would be considerably more handy and convenient to use, for there would be no process of generation for the driver to look after; and probably the cylinder required to hold a certain volume of gas would be smaller and easier to pack under the car than a generator of equivalent capacity. On the other hand, carbide can be procured almost anywhere, at least in all large towns, while an extra supply could easily be carried about from place to place when taking long journeys; the store of compressed gas, however, could be replenished at only a very small number of places.

Regarding the uses of lumber in China, it appears from a recent consular report that more wood is used there for coffins than for any other purpose. The coffins are made of lumber from 4 to 10 inches thick. It is not a high estimate to say that from 8,000,000,000 to 10,000,000,000 feet of lumber are annually thus utilised. The great majority of houses are built of mud and bricks, or mud and straw or millet stalks; very little lumber is used. The roofs are made of either tiles or straw and mud. Next to coffins, the greatest use for lumber in China is for boats. While there are no statistics on the subject, it is safe to say that the number of craft runs into the millions. The vast coast line, the enormous rivers, the wonderful canal systems of China, all are teeming with boats of every description, propelled by steam, sail, towline, or oars operated by both hand and foot. Through vast areas of country, rivers and canals form the only highways; in some sections they are more numerous than the common roads in densely populated agricultural districts of Europe and America. Enormous quantities of wooden buckets and small wooden tubs also are used in

every district of China. Considering all this, the almost entire lack of sawmills appears remarkable, and is suggestive of a possible trade in this line, at Tientsin, for example, Shanghai, Hankau, and a number of other places. Cheap mills, built for cutting a few thousand feet of light logs a day, are mentioned as the most likely ones to meet with sale.

It is a little astonishing how far and wide we search and what trouble and expense we often undergo and incur for a thing which, if it were but known, is all the time within easy reach. An instance of this, in a small way and one which is at the same time an illustration of the value of testing what may at first seem the impracticable, recently came to notice. In a certain printing telegraph system what is termed the printing lever is placed within a tube, about ten inches from one end. At this end of the tube it is necessary to place an electro-magnet which should operate the printing lever. Communication between the armature lever of the electro-magnet and the printing lever was first made by means of an ordinary small iron wire. The wire had comparatively little work to do, but it was moved back and forth about one quarter of an inch, ten or twelve times per second. In a very short time the iron wire broke. All kinds of wire, cords, and chains were thereafter tried, but, for a long time nothing was found that would do this work. In almost every case the iron or steel wire used would, after a very short interval, attenuate at one point and break. At last, one day, while the inventor was racking his brain to discover a durable connecting medium between the printing lever and the electro-magnet, his fingers happened to rest on the cane-bottom seat of the chair on which he was resting. It occurred to him that here was a material that withstands a good deal of rough usage, and a piece of rattan was tried. The result was complete success. One piece of this material has lasted for years and shows no present signs of deterioration. Just why this most unlikely material should resist, without apparent wear or tear, the usage which so quickly destroyed the usefulness of the best iron, steel, aluminium, and gut rods, cords and chains, awaits explanation.

Under a French law still in force, the communication by a factory workman, clerk, or manager of a trade secret to a foreigner, or to a Frenchman resident abroad, is punishable with a term of imprisonment ranging from two to five years, and with a fine ranging from 500 to 20,000 francs. The culprit is, moreover, deprived of his civil rights, and kept under police surveillance for a period of from five to ten years after his release from prison. A similar communication made to a Frenchman resident in France, is less heavily punished, the term of imprisonment varying in this case three months to two years, and the fine from 15 to 200 francs. In the case of a State arms or ammunition factory, the maximum penalty must be imposed. It appears, further, that in France the proprietor of a factory has a right, without reserve, to the discoveries and inventions made within his field of work by any of his employes.

One advantage that often comes from the use of the electric motor for machine driving is the comparative ease with which it may be ascertained whether a particular piece of machinery thus driven is operating at its highest efficiency. This can be done by comparing the power consumed by the motor in driving it with the power used in driving another similar machine. For example, it has more than once been found that certain printing presses of a given make have been consuming from one to two horse-power more than another similar press, notwithstanding that the makers pronounced their apparatus in perfect running order, and in consequence placed the cause of the discrepancy on the electric motor. A brake test of the

A TEN-COUPLED COMPOUND LOCOMOTIVE ON THE ATCHISON, TOPEKA & SANTA FE RAILROAD BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

motors or an exchange of motors quickly showed the fallacy of this contention, and an easing-up of the bearings of the press in different places has usually sufficed to get rid of this waste of power.

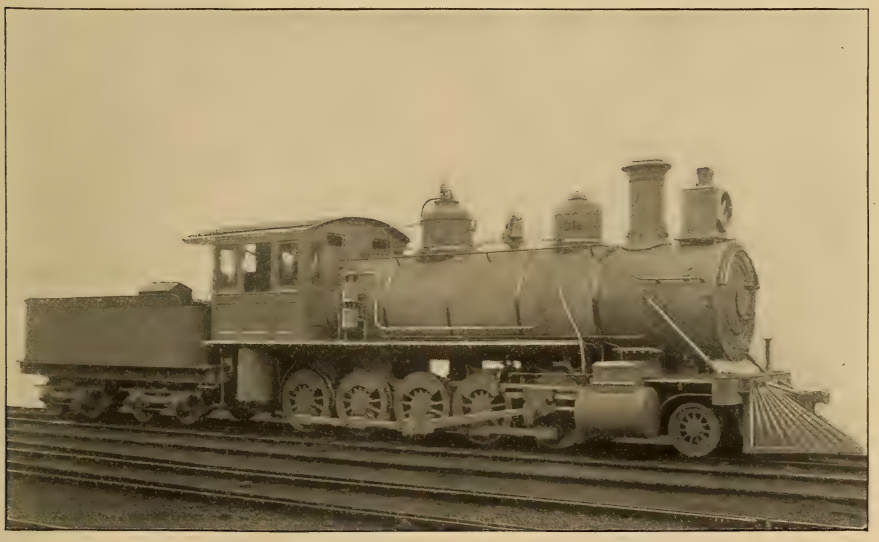
INCREASE of output of machinery driven by electric motors is, after all, the great desideratum which is achieved, and far outweighs in importance the several other advantages incidental to electric driving,—the saving of head room, for example, the absence of long lines of shafting, and the avoidance of power wastes. Indeed, the value of the power, whether furnished by shafting or by the electric motor, as compared with the importance of increased product, is nearly negligible.

"I REMEMBER," said a bridge contractor some time ago while on the subject of workmen's dare-deviltries, "when working at the big bridge across the Niagara, when the two cantilever arms had approached within fifty feet of each other, a keen rivalry as to who should be the first to cross sprang up among the men. A long plank connected the two arms, leaving about two and a half feet of support at each end. Strict orders were issued that no one should attempt to cross the plank upon penalty of instant dismissal. At the noon hour I suddenly heard a great shout from the men, who were all starting up. Raising my eyes, I saw a man step on the end of that plank, stop a minute, and look down into the whirlpool below. I knew he was going to cross and I shouted to him, but he was too high up to hear. Deliberately he walked out until he reached the middle of the plank. It sagged far down with his weight until I could see light between the two short supporting ends and the cantilevers on which they rested. He saw the end in front of him do this, hesitated, and looked back to see how the other end was. I thought he was going to turn. He stopped, grasped both edges of the plank with his hands, and, throwing his feet up, stood on his head, kicking his legs in the air, cracking his heels together, and yelling to the terrified on-lookers. This he did for about a minute—it seemed to me like forty. Then he let his feet down, stood up, waved his hat, and trotted along the plank to the other side, slid down one

of the braces hand over hand, and regained the ground. We discharged him, of course, but what did he care? He got all the glory, his fellows envied him, and he could command work anywhere."

In the article on "British Tank Locomotives," published elsewhere in this issue, reference is made to ten-coupled engines of which type none are at present in service anywhere in Great Britain. It may be worth noting, therefore, that the first locomotive of this class in the United States,—the "Decapod" class, as it was termed,—was built by the Baldwin Locomotive Works in 1886, for the Northern Pacific Railroad. This was followed by a number of tank engines, by the same builders, for the St. Clair river tunnel on the line of the Grand Trunk Railway, and, later still, by a lot of four heavy freight locomotives for the Erie Railway for operating on a heavy grade east of Susquehanna, the object being to substitute one locomotive where two had previously been employed. Another ten-coupled engine of Baldwin make was recently supplied to the Minneapolis, St. Paul & Sault Ste. Marie Railway, while the last instance is a locomotive built for the Atchison, Topeka & Sante Fé Railway, an illustration of it being given on the preceding page, representing the engine on the Raton Mountain in New Mexico. An illustration is given also of the Northern Pacific engine above mentioned. This engine has 22 × 26-inch cylinders, and 45-inch driving wheels, with somewhat over 130,000 pounds on the drivers. The total weight of the engine is 145,000 pounds. The Atchison, Topeka & Santa Fé engine is a compound with 19 × 32 × 32-inch cylinders, 57-inch drivers, and a total weight of about 267,800 pounds. The weight on the drivers is about 237,800 pounds.

When Roentgen discovered the X-rays it was, doubtless, imagined by some that the end of research along this line had been reached, when possibly it was but scarcely begun. The recent remarkable discoveries by M. and Mme. Curie, of Paris, which point in the direction of obtaining light without heat, are a confirmation of the latter view. M. Becquerel in 1896 showed that uranium compounds, especially when prepared



ONE OF THE EARLY TEN-COUPLED LOCOMOTIVES ON THE NORTHERN PACIFIC RAILROAD

in the electric furnace, possess high radio-activity, and while their rays are not visible, they possess the power, like light and X-rays, of affecting photographic plates. These rays also have the property of facilitating the discharge of a condenser when they fall upon the air between the plates of such an instrument, thus seemingly making the air a conductor of electricity. The Curies, following Becquerel, succeeded in obtaining from residues of uranium a number of radioactive substances, one of which, termed radium, is said to be 100,000 times more powerful than uranium. Radium is somewhat similar to barium, and possesses the property of glowing in the dark without previous exposure to light, and it imparts this property to other substances, which they retain for a lengthened period. It is, in effect, a constant source of X-rays and cathode rays, and, like X-rays, has the power to produce serious burns on the human skin. Fortunately, this harmful effect may be obviated by enclosing the substance in a leaden tube. The speed of the radium rays is about half that of light, or about 92,500 miles per second. Becquerel has estimated that the waste or loss by radiation from this substance from a half-inch surface would be only one milligram in 1,000,000,000 years. In the treatment of 100,000 tons of uranium residues not more than two pounds of radium are obtained. Hence, the price of this wonderful substance is high, being, in its most refined state, about $35, or £7, per gram.

Sir William Crookes, whose name is lastingly connected with the phenomena of radiant energy, offers an explanation of the radiation of energy by metals, which, briefly, is as follows:—He conceives a target capable of mechanically sifting from the molecules of the surrounding air the quick from the slow movers. This sifting of the swift-moving molecules is effected in liquids whenever they evaporate, and in the case of the constituents of the atmosphere whenever these are light enough to drift away, molecule by molecule. He conceives such a target as a piece of metal cooler than the surrounding air, acquiring the energy that gradually raises its temperature from the outstanding effect of all its encounters with the molecules of the air about it. He assumes another target of such a structure that it throws off the slow-moving molecules with little exchange of energy, but is so influenced by the quick-moving missiles that it appropriates to itself some of the energy. Let uranium or polonium (also discovered by Madame Curie and so named by her in honour of her native country, Poland), bodies of densest atoms, have a structure that enables them to throw off the slow-moving molecules of the atmosphere, while the quick-moving molecules, smashing onto the surface, have their energy reduced, while that of the target is correspondingly increased. The energy thus gained might then be employed partly in dissociating some of the molecules of the gas (or in inducing some other condition which has the effect of rendering the neighbouring air in some degree a conductor of electricity), and partly in originating an undulation through the ether, which, as it takes its rise in phenomena so disconnected as the impacts of the molecules of the air, must furnish a large contingent of light waves of short-wave length. The reduction of the speed of the quick-moving molecules would cool the layer of air to which they belong, but this cooling would rapidly be compensated by radiation and conduction from the surrounding atmosphere. Under ordinary circumstances the difference of temperature would scarcely be perceptible, and the metal would thus appear to perpetually emit rays of energy without apparent means of restoration.

A short time ago, says *The Foundry*, in one of the big steel foundries a 15-ton ladle full of molten steel, through the breaking of a chain, dropped 3 feet to the floor without causing any greater

damage than the spilling of about 100 pounds of metal. It was a lucky drop, and the part of the floor where the ladle fell was almost level. Hardly anyone in the shop knew what a close escape a large number of men had had from death or injury. The question arises: —What would have happened if the link which broke had retained its strength for one or two minutes longer, when the ladle would have been suspended at a distance of not less than 5 feet from the floor and above flasks which are poured on an incline? It would seem as if some sort of an inspection ought to be made of foundry chains used in hoisting ladles of metal at regular intervals to prevent any such accidents as sometimes do occur. It is really a wonder that they are not more numerous.

It is a well-known fact that an unpleasant smell makes itself manifest in buildings when the heating apparatus is employed for the first time after a long interval of rest, even if the temperature does not reach the boiling-point of water. Many reasons have been put forward in explanation of this fact, and it has been frequently asserted that the smell was due to a dry distillation of the dust particles, though this could take place only at temperatures greatly exceeding those likely to arise in the usual forms of low-pressure steam apparatus, or those depending on the circulation of hot water. In order to arrive at the real cause of this evil, exhaustive examinations have been made in Germany of the different kinds of dust deposited in dwellings and school buildings. The results of these examinations as recorded in the *Gesundheits-Ingenieur* and abstracted in the volume of Foreign Abstracts of the Institution of Civil Engineers, have shown the fine dust, collected with due precautions, to consist largely, and in some cases wholly, of very minutely divided horsedung. Moreover, the dust found on the cold pipes always contained a large proportion of moisture and was rich in micro-organisms. When the apparatus is first set in operation the warmth induces these organisms to vegetate in great numbers and results in setting free large volumes of ammonia. This gives rise to the unpleasant smell and has an irritating effect on the mucous membrane. In order to avoid the smells, all that is needed is to thoroughly clean the pipes and coils before the fires are lighted.

Speaking broadly, remarked the London *Engineer* in a recent article on "Automatic Stokers," it may be said that the paramount defect of the automatic stoker is lack of flexibility. It depends for its success on plenty of boiler power and steady use. It will not stand forcing. If the stoker is so designed that it will provide for the evaporation of, say, 10,000 pounds of water per hour, well and good; but any attempt to run it up to 15,000 pounds will end in ultimate failure. We are quite aware that any number of testimonials are available concerning a dozen different stokers that will comply with the required conditions. These testimonials are of no weight in the face of the fact that, under certain conditions, the automatic system fails in the way we have indicated; and the reason is obvious. To burn coal at various rates on the same grate at irregular intervals requires human intelligence. The automatic stokers have none. In a general way, they all depend on the principle of carrying fresh coal in at the fire-door end, which coal is subsequently pushed or otherwise conveyed to the bridge end of the grate, by which time it is supposed to be all burned; or else revolving fans or their equivalents "flick" the coal over the surface of the fire. In either case it is next to impossible to keep the grates evenly covered by a machine if the demand for steam varies; that is to say, the machine has one pace which suits it better than any other. An able fireman will see that holes do not burn through his fires. He will always plant a shovelful of coal just in the place where it is wanted. No machine can do this. There are, beyond doubt, hundreds of cases in which no

special intelligence of any kind is needed on the part of a human stoker. The demand for steam is steady and continuous from morning to night. Textile mills of all kinds, pumping stations, flour mills, breweries, and several other places may be cited in which about the same quantity of water is evaporated every working day the whole year round. There is plenty of boiler power; no sudden demands are ever made on the boilers. Conditions such as these perfectly suit the automatic stokers. Who, for example, can devise anything more adapted to such conditions than the old Jukes chain grate, which is now working its way into favour again under different titles? We see the thin sheet of small coal, carefully spread over the grate, slowly advancing into the furnace, and we know that the supply of coal to the grate, the supply of air below the grate, and the rate of advance of the grate have all been so perfectly adjusted and put in tune, so to speak, that the combustion of the coal will be just completed by the time it reaches the bridge. Alter the relations of the three factors in any way and see what follows. A little increase of draught, and holes are burned through the fire near the bridge, because the coal is consumed so rapidly that the further end of the grate is left bare; reduce the draught, and, conversely, unburned coal is pushed over the bridge. We do not for a moment say that it is impossible to "tune" the furnace for a greater effort than the normal, but we do say that such tuning does not appear to be carried out successfully in practice.

THERE is something highly attractive in the idea of machine firing; something repulsive in the idea of hand firing. For three-fourths of a century inventors have addressed themselves to getting over the difficulties attending automatic stoking. The shelves of the Patent Office Library are crowded with ingenious specifications for machines to burn coal. Fortunes have been lost in the pursuit of the thing needed. Fortunes have been made, it is said, by those who have achieved even a certain measure of success. With all this we still find hand firing in favour. We seem to be as far off as ever from the millennium. If automatic stokers did always when wanted what they do in a great many places now, hand firing would long since have become strictly exceptional. Perhaps the human and the machine stoker may yet be combined, and a system devised by which the man finds the intelligence and the machine does the hard work.

WHEN the two elements, oxygen and aluminium, are brought together under certain conditions, a chemical reaction is started of such an energetic nature as to produce a temperature hitherto obtained only by the electric arc. Further, the action takes place almost instantaneously. The necessary oxygen is obtained from its chemical combinations, principally the metallic oxides. Many years ago it was known that metallic chlorides, and in a less degree metallic oxides, when mixed with powdered aluminium under certain temperature conditions set up a vigorous chemical action. But it was difficult to start the reaction. As the mixture was placed in a crucible which was put in a suitable furnace, any regulation of the reaction was impossible, because of its sudden and vigorous nature. It remained for Dr. Hans Goldschmidt, of Essen-Ruhr, Germany, to discover a practicable method of applying the principle, advantage being taken of the fact that certain superoxides part readily with their oxygen and produce intense heat. A small quantity of barium superoxide and powdered aluminium is placed upon the mixture of metallic oxide and aluminium contained in a crucible. This is ignited with an ordinary match, when the reaction at once begins, and is continued as long as desirable by simply adding more material. It has been estimated that the temperature is about 3000° C. As a result of this simple process it is possible to apply an intense heat at any place without any compli-

cated appliances and at a small cost. The process, which is controlled by The Allgemeine Thermit Gesellschaft, Ltd., of Essen-Ruhr, Germany, is now used for the production of pure metals, such as chromium and manganese; for the welding of wrought-iron gas and water pipes and rails, and for repairing shafting, steel castings, etc.

A RECENT report of the Minister of Public Works to the president of the French Republic contains interesting information regarding the coal, iron, and other mining industries of France, a résumé of which is given in a just issued United States Consular Report. From this it appears that the principal French coal basin, which is located in the Departments of Nord and Pas-de-Calais, produces 20,000,000 tons of the 33,000,000 tons mined in France annually, or about two-thirds of the total output. The extraction of coal in the Department of Nord remains practically stationary, while the production of the mines of the Pas-de-Calais is increasing annually. From 1886 to 1900 the annual increase has been 650,000 tons, with every indication of its continuing. The coal basin of St. Etienne, which comes second, is much less important than the above. Its output of 4,000,000 tons,—about 12 per cent. of the total production,—does not show any marked increase. Then follows the basins of the Centre and of the Midi, which have a comparatively small output. The most important mines in these districts,—those of the Gard and of the Bourgogne,—produce about 2,000,000 tons each, or 6 per cent. of the total output, and they do not increase their production from year to year to any great extent. Certain of the coal basins of France,—that of Allier, for example, —show unmistakable signs of a still further decrease in their output, without the prospect of any betterment from new explorations.

THE production of iron ore in France is centered principally in three districts: —that of the northeast, or the Meurthe-et-Moselle, is the most important, producing 4,500,000 tons of the 5,500,000 tons of iron ore mined in France annually; that of the Pyrenées, producing 250,000 tons; and that of Normandy, 150,000 tons. The last may be said to be in its infancy. From its geographical position, its ores are generally sent to foreign countries, while the ores produced in the other districts are consumed by the metallurgical industries of France.

JULIAN KENNEDY

A BIOGRAPHICAL SKETCH

IN the field of iron and steel metallurgy there is to-day probably no better known engineer in the country than Julian Kennedy, of whom an excellent portrait appears in this issue.

Mr. Kennedy attended common school in Ohio and also Poland Union Seminary, leaving this institution in 1869, at the age of seventeen, to become a draughtsman in the construction of the blast furnace of the Struthers Iron Company, under his father's supervision. Upon the completion of this he ran blowing engines and other steam machinery for about a year, after which he became shipping clerk at the same place for another year.

In 1872 he entered the Sheffield

Scientific School of Yale College, graduating in 1875, taking a course in civil engineering until the end of the junior year, after which, by special permission of the faculty, he was allowed to change to the course of chemistry. By working overtime he made up two years' work in this course during his last year. After graduation he was appointed instructor in physics, and remained at the school in this capacity during the year 1875 and 1876, taking at the same time a post-graduate course in chemistry of iron and steel, and also a special course in higher mathematics and astronomy. During this time he also had charge of the physical laboratory, and gave a course of illustrated lectures on physics to the students of several seminaries in New Haven, lecturing during the same period in the mechanics course, given in the lecture room of the scientific school.

In 1876 and 1877 Mr. Kennedy was superintendent of blast furnaces of the Brier Hill Iron Company, at Youngstown, Ohio. In 1877 he became superintendent of the blast furnace of the Struthers Iron Company, at Struthers, Ohio; and in the following years served successively as superintendent of the Morse Bridge Works, at Youngstown, Ohio; superintendent of blast furnaces at the Edgar-Thompson Steel Works, at Braddock, Pa.; superintendent of the Lucy Furnaces, at Pittsburg; and general superintendent for Messrs. Carnegie, Phipps & Co., with headquarters at Homestead. In all these works he had charge of both construction and operation, and all the time that he was connected with either the Edgar-Thompson or the Lucy Furnaces, these furnaces held the world's record for output of pig iron.

In 1888 he became chief engineer of the Latrobe Steel Works, at Latrobe, Pa., and had charge of the construction of their works, and in 1890, while continuing to be their chief engineer, opened an office in Pittsburg. Since that time he has been doing a general consulting and contracting engineering business, and has been connected as consulting engineer with nearly every important steel works in the United States. He has also done a great deal of engineering work in England, Germany, Austria, and Russia.

Mr. Kennedy has taken out a large number of patents, most of which are in successful use, nearly all being in connection with the manufacture of iron and steel, and has also acted as expert in a large number of patent suits. Among his inventions are improvements on hot blast stoves, blast furnace filling devices and improvements in blowing engines, reversing engines, and blooming mills and manipulators. These have all gone into use very largely in many works.

During his college days, Mr. Kennedy was a member of the Connecticut Academy of Sciences, and is now a member of the Engineers' Society of Western Pennsylvania, the American Institute of Mining Engineers, and the Iron and Steel Institute. He is also a member of the Duquesne Club, of Pittsburg. In 1900, Yale University conferred upon him the honorary degree of master of arts.

E. W. Bliss

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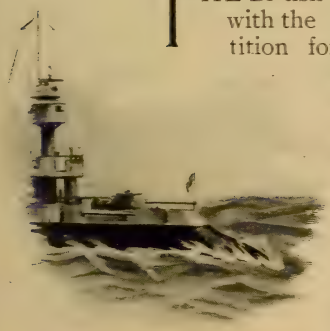
CASSIER'S MAGAZINE

VOL. XXII OCTOBER, 1902 No. 6

THE BRITISH FLEET. 1889-1902

By Archibald S. Hurd, Author of "Naval Efficiency: The War-Readiness of the Fleet"



THE British people are faced with the keenest competition for the markets of the world, and the continued supremacy of the mercantile marine of Great Britain is seriously threatened. So also Britain's position as a naval power is assailed on all sides. Fourteen years ago the only rivals in naval armaments were France and Russia. Now great fleets are being built by Germany and the United States, and, in the Far East, by Japan. Fortunately it is not necessary for Englishmen to take serious warning by the strides which Americans are making and which will give them more battleships than France in a few years, while the recent treaty with Japan has converted that country into Great Britain's close ally.

The efforts of her neighbours across the English Channel, on the other hand, are watched with concern and some apprehension, and, according to many prophets, the British fleet is unequal to the task which might devolve upon it in case of war afloat. Lord Charles Beresford has put the matter in a nutshell,—"Great Britain is outside the zone of extreme danger, but is not yet within the zone of safety against any possible combination."

The taxpayer who has made great sacrifices for the strengthening of the Navy is not unnaturally apt to become discouraged in face of so many pessimistic statements, and to ask what has become of all the money which has been voted, year by year, for the Navy. It may be useful, therefore, to forget for the moment the problems of relative strength, and, ignoring for the most part all the discussion suggested by the growth of neighbouring fleets, to consider the British fleet which has been built since the passing of the Naval Defence Act as a great, in fact, the greatest, national asset,—in short, "take stock," to use a commercial phrase.

In round figures the aggregate outlay on Great Britain's Navy in the past fourteen years,—in other words, since the passing of the Naval Defence Act,—has been £298,500,000. Of this colossal sum £100,000 have been devoted to the construction of new men-of-war, the vessels on which the Empire will depend mainly for its security when war occurs. This colossal expenditure is one of the burdens of empire. "Is it not too heavy," it may be asked, and the question is a reasonable one. Putting aside the main point, that

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British naval expenditure has never grown in anticipation, but always as a reply to the action of other nations, we find that the fleet, and not, be it remembered, the Army,—essential as is a small land force capable of ready expansion,—guards not less than a quarter of the globe from aggression, protects more than a quarter of the population of the world, secures safety to half as much merchant shipping as all the other countries of the world combined, and, most important of all to residents in the British islands, frees them from the danger of starvation, the most terrible of all scourges which an enemy could inflict.

This is the responsibility that rests on the ever-patrolling squadrons of Great Britain. The magnitude of the Empire and its trade and the consequent jealousy of Great Britain's neighbours, and the liability to have food supplies and raw material kept from her,—these considerations sufficiently answer the question, "Do we pay too much for the Navy?"

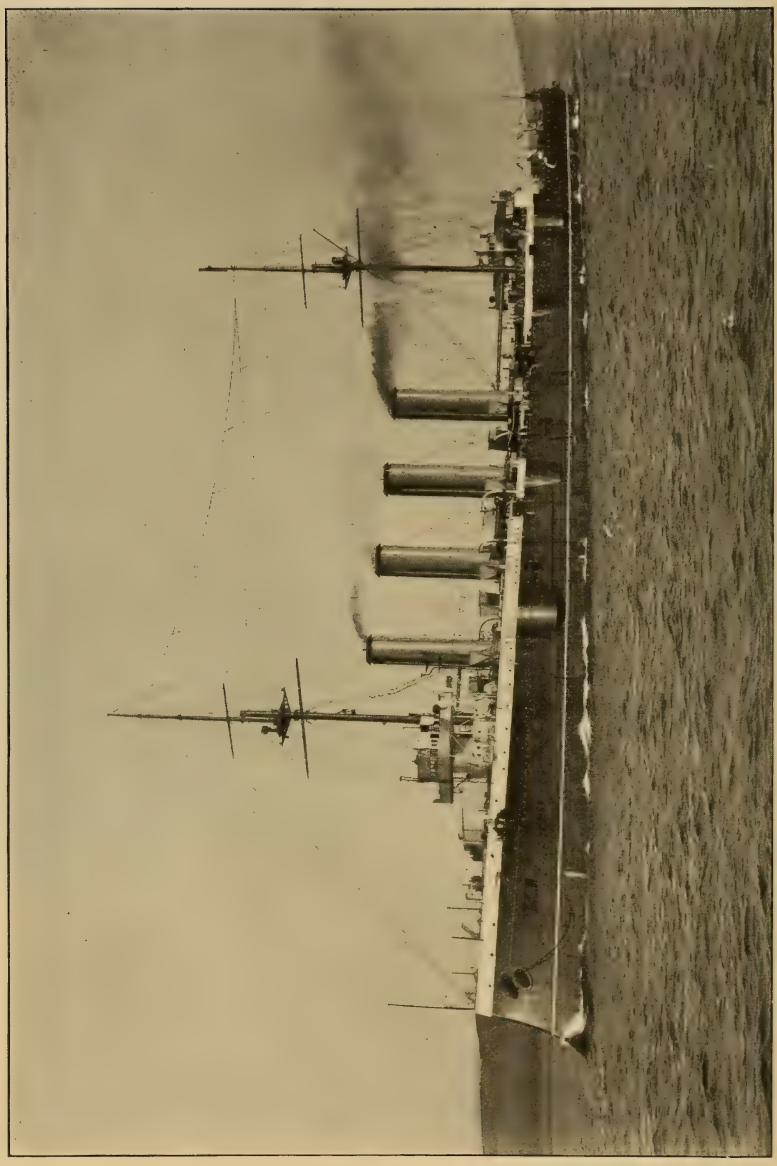
A committee of the House of Commons has been appointed to enquire into the growth of national expenditure, and naturally consideration will be given to the growth of the yearly provision for the defence of the Empire. Investigation into this matter will bring the committee face to face with the most glaring instance of national inconsistency. The Navy is always referred to as the "first line of defence,"—it is really the only line, but that may pass,—yet practically throughout the nineteenth century the nation devoted to the Home Army millions in excess of the sums set aside for the Navy.

In the first seventy years of the century the disproportion was particularly glaring; the exact figures may be seen from the Treasury's statistics on "Public Income and Expenditure." One period, and that recent, may be mentioned by way of illustration. In the ten years ended on March 31, 1895, the nation spent on the Home Army £178,045,000, and on the Navy £145,770,000 in the same period, the excess in favour of the Army amounting to £32,275,000, or an annual average of over three and a quarter millions. Since then the Navy has received slightly more money than the Home Army, but this fact does not indicate that the people of the British Empire have yet realised that their sole defence in a great war will be the fleet. The Navy is the Navy of the Empire, and can expect no reinforcements from any source on the outbreak of war. What the fleet is when hostilities occur, that will be the fleet on which the Empie will have to rrely.

A battleship, on an average, takes three years to build, and a bluejacket

LORD CHARLES BERESFORD

cannot be properly trained under five years. On the other hand, the figures in the army estimates presented to the British House of Commons deal only with the Home Army, which is merely a moiety of the armed forces which would be available in case of a serious land campaign. This has been effectively illustrated in the course of the South African war. The British War Office, in the hour of need, enlisted thousands of civilians in the British Isles, many of whom had little or no knowledge of the requisites for war; thousands of colonials, men of open-air training and splendid



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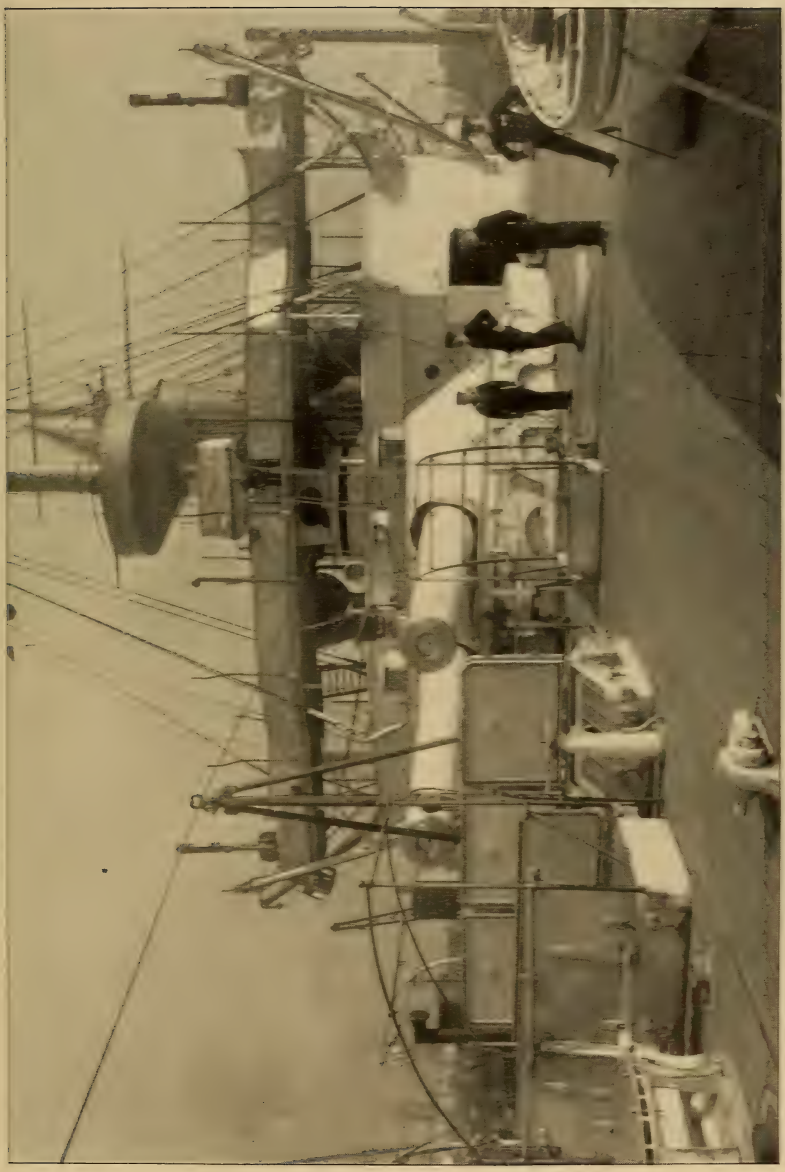
THE TWIN-SCREW PROTECTED CRUISER "GOOD HOPE" BUILT BY THE FAIRFIELD SHIPBUILDING & ENGINEERING CO., LTD., GOVAN, GLASGOW. LENGTH, 500 FEET. BEAM, 71 FEET. DISPLACEMENT, 14,100 TONS. I. H. P., 31,000. SPEED, 23 KNOTS



THE QUARTERDECK OF H. M. S. "IRRESISTIBLE"

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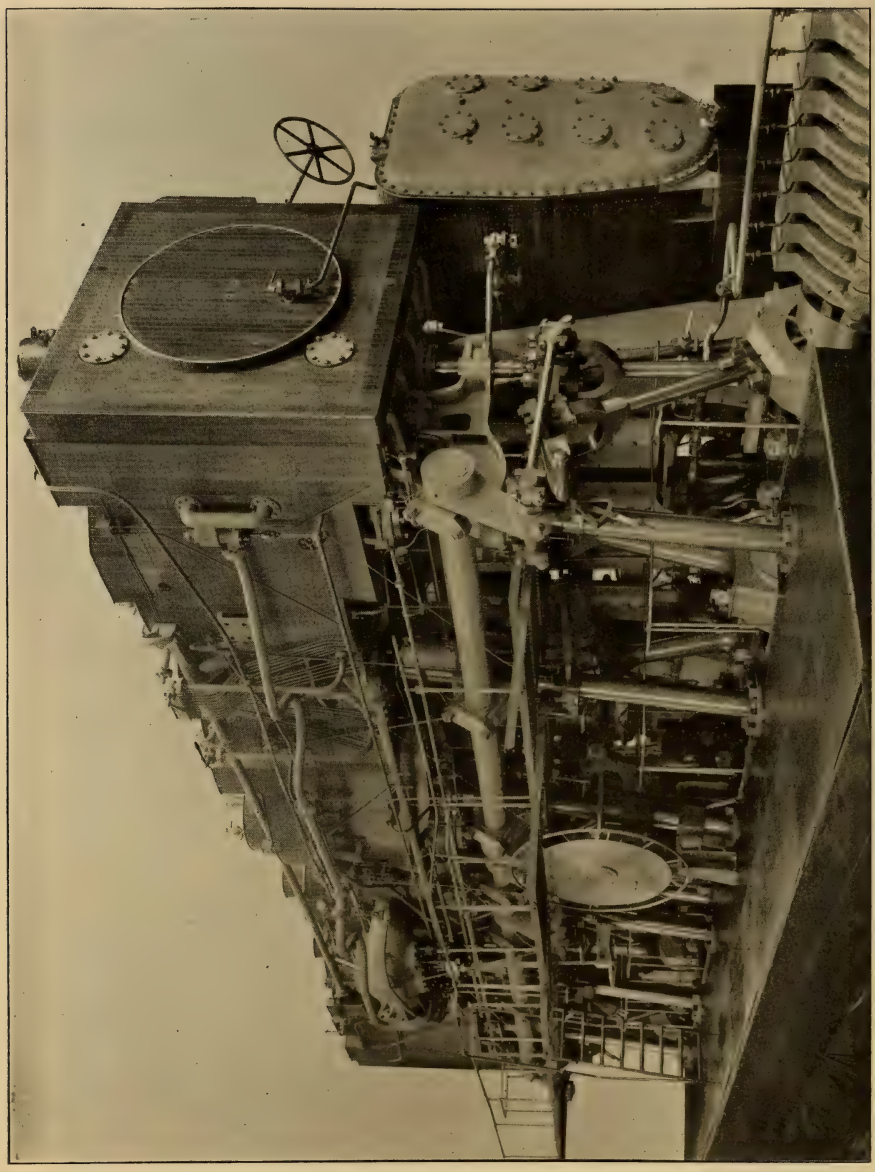

ENGINES OF THE BRITISH TWIN-SCREW CRUISER "GOOD HOPE." TWO CYLINDERS OF 43½ INCHES DIAMETER; TWO CYLINDERS OF 71 INCHES; AND FOUR CYLINDERS OF 81½ INCHES. STROKE, 4 FEET. I. H. P., 31,000. BUILT BY THE FAIRFIELD SHIPBUILDING & ENGINEERING CO., LTD., GOVAN, GLASGOW

stamina, and was also able to draw on India.

Including the Indian Army and the regular colonial forces, the Army of the Empire numbers a million and a quarter men, and behind these soldiers and volunteers are several million men who could be made into fighters in a week or two. That this is true was revealed during the South African war. All that is required is an ample supply of rifles and ammunition to greatly swell the Imperial Army in face of any aggressive force. Who that foe would be, it is impossible to speculate. Great Britain has no land frontiers, except in India and Canada, and the latter country's openness to attack does not need to be taken into serious account if blood is thicker than water. There is nothing to fear from the huge armed camps of Europe. So long as Britain holds the seas in supreme command, so long, in other words, as she fulfills her destiny and her obligation to those from whom she has inherited the Empire, not a hundred men can be moved by water to any distant field of action where they might be a danger to her.

India is the only exception, and that *imperium in imperio* presents military problems of its own and supports an army of its own,—an army, however, which, in a measure, is available for service in any part of the Empire; the greater the need, the greater would be India's contributions of armed men, for the British Empire must stand or fall as a whole.

The land forces of the Empire cost approximately £50,000,000 a year, while the naval forces of the Empire, including the small local forces of the Colonies, cost less than £35,000,000. If, therefore, the Navy is the Empire's "first line of defence," the conviction of the peoples who claim King Edward as Sovereign Lord is curiously expressed.

The past fourteen years have been a period of remarkable naval development, and perhaps the point that strikes an observer most is the awakening to the fact that warships exist that they may be able to fight. In 1889 there were ships whose gunnery was discreditable. The men behind the guns had few serious opportunities to practice, because under no circumstances could the pretty "paint work" be dirtied, for on that, to a great extent, senior executive officers' promotion depended.

As Sir John Colomb has pointed out, it was not until 1884 that, as a result of his agitation, any money was voted for the collection of information as to the progress of foreign fleets, and as late as 1888 Great Britain was devoting annually £18,300 to military intelligence and only £5000 to naval intelligence. Lord Charles Beresford and Sir John Colomb, Mr. Spenser Wilkinson, Sir Charles Dilke, and some others

SIR CHARLES DILKE

roused public interest in this question. The Navy had no shred of organisation for war, and it was to call attention to the deficiencies of the naval administration that Lord Charles Beresford resigned his seat at the Admiralty.

Great Britain has a Naval Intelligence Department to-day on which, as Sir John Colomb recently remarked, are expended £17,726, while the Military Intelligence Department absorbs no less than £24,949. The difference is considerable, yet naval, not military, intel-

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THE ARMOURED CRUISER "CRESSY." BUILT BY THE FAIRFIELD SHIPBUILDING & ENGINEERING CO., LTD., GOVAN, GLASGOW
LENGTH, 440 FEET. BEAM, 69 FEET. DISPLACEMENT, 12,000 TONS. I. H. P., 21,240. SPEED, 20.7 KNOTS

ligence is of all importance to Great Britain; the armies of Europe may do what they like without British safety being affected so long as the fleet is able to carry out its appointed task and hold the seas.

The greatest of all naval changes of the past fourteen years is that we have an organisation of a kind for war. Of this more must be said at a later stage. Some other points of contrast suggest themselves in glancing back over this period, which may be summarised thus:—

The annual net expenditure on the Navy has been doubled, having increased from £15,270,000 in 1889 to £31,255,000 in the present year.

The sum annually devoted to the construction of new ships (all expended in Great Britain, of course) has nearly trebled, having risen from £3,627,729 in 1889 to £9,446,171 in the present year.

The personnel of the fleet has been augmented more than twofold. It stood at 65,400 in 1889, whilst this year 122,500 officers and men were voted.

The displacement of the largest battleship afloat in 1889,—the *Royal Sovereign* type, costing £852,000 to £877,000,—was 14,150 tons, and the speed was 15 knots under normal draught, and 17 knots under forced draught. To-day Great Britain is building battleships each with a displacement of 16,350 tons, and costing probably over one million and a quarter sterling, with a speed of 18½ knots. The smaller new battleships of the *Duncan* class have a speed of 19 knots.

The largest cruiser, the *Blenheim*,—only protected,—of 1889 had a displacement of 9000 tons and a normal speed of just over 20 knots with 20,000 indicated horse-power; to-day we are building cruisers,—the *Drake* and her sisters,—so heavily armoured as to be practically swift battleships, with a displacement of 14,100 tons and a normal speed of over 23 knots with 30,000 indicated horse-power.

The largest gun of the latest battleships in 1889 was the 67-ton, 13.5-inch weapon, capable of perforating 27.6 inches of wrought iron at 2000 yards; to-day the largest gun is the 50-ton, 12-inch piece, perforating 31.6 inches of wrought iron at the same distance, with cordite, and much more with any efficient nitro cellulose powder.

The largest gun usually carried by cruisers in 1889 was the 7-ton, 6-inch weapon, capable of perforating about 10 inches of wrought iron at 2000 yards; to-day we have the same calibre piece which can perforate 13.4 inches. The latest medium sized cruisers of 11,200 tons are to have the new 7.5-inch weapon which can go through 19.3 inches of wrought iron.

These are merely a few casual index points of the period which has witnessed the introduction of the torpedo-boat destroyer and the submarine boat as weapons of war, and has seen remarkable developments in the power of the gun and the torpedo, the latter having been converted by the gyroscope into a weapon as certain as the gun.

In every department of the fleet the past fourteen years have been a period of extraordinary development, and in days when progress is so swift it is inevitable that many British men-of-war carry equipments which are not the final product of the inventor. In an age when progress is so rapid it is impossible, in a force as large and widely distributed as the British fleet, that it should be otherwise. The lesson for the British people is to build sufficiently of all classes of ships, so far as the resources available will allow, and to complete swiftly.

In introducing the Naval Defence Act, Lord George Hamilton said:—"Rapidity of construction means economy, because delay occasions twofold waste,—not only does the ship cost more in construction, but the longer it is on the stocks, the less time it is alive as an effective ship, and therefore the less use you get out of it."

After this statement the British Government yards astonished the world by building and completing for the pennant two battleships, the *Majestic* and the *Magnificent*, in twenty-two and twenty-four months, respectively, from the date of laying down the keel plates. Since

THE HOSPITAL SHIP "MAINE"

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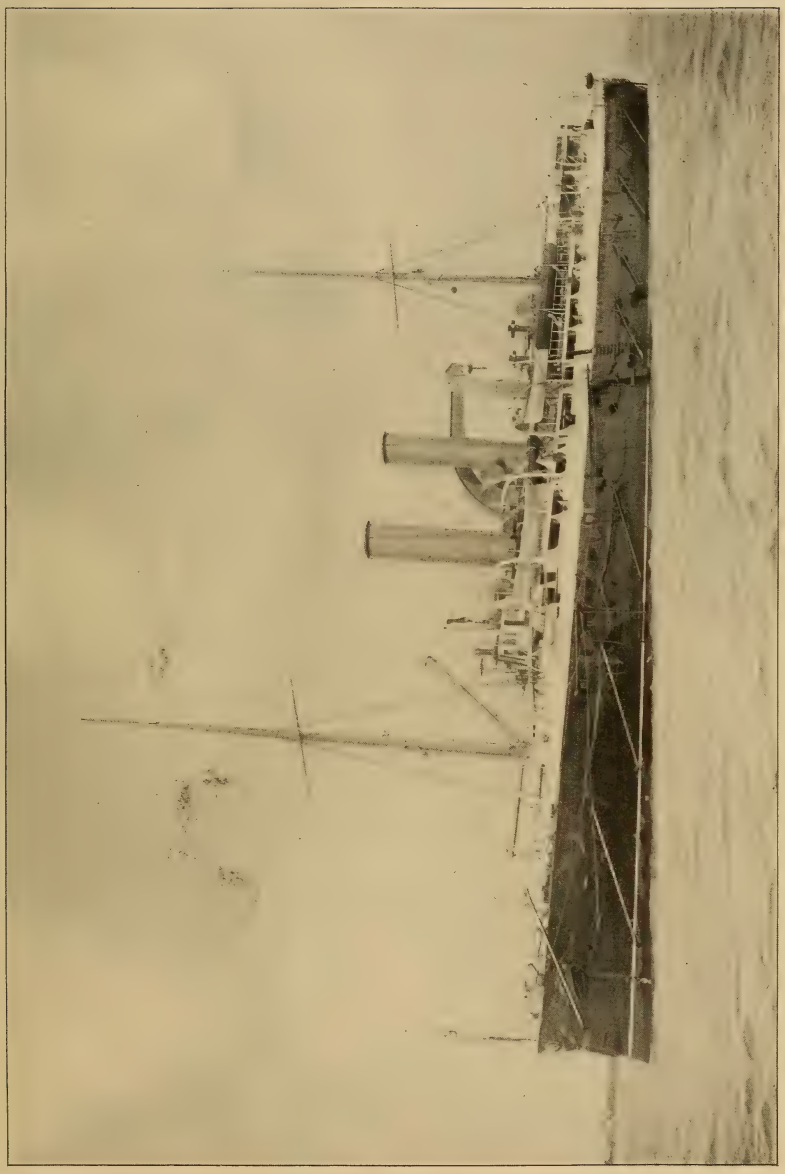

THE REPAIR SHIP "VULCAN"

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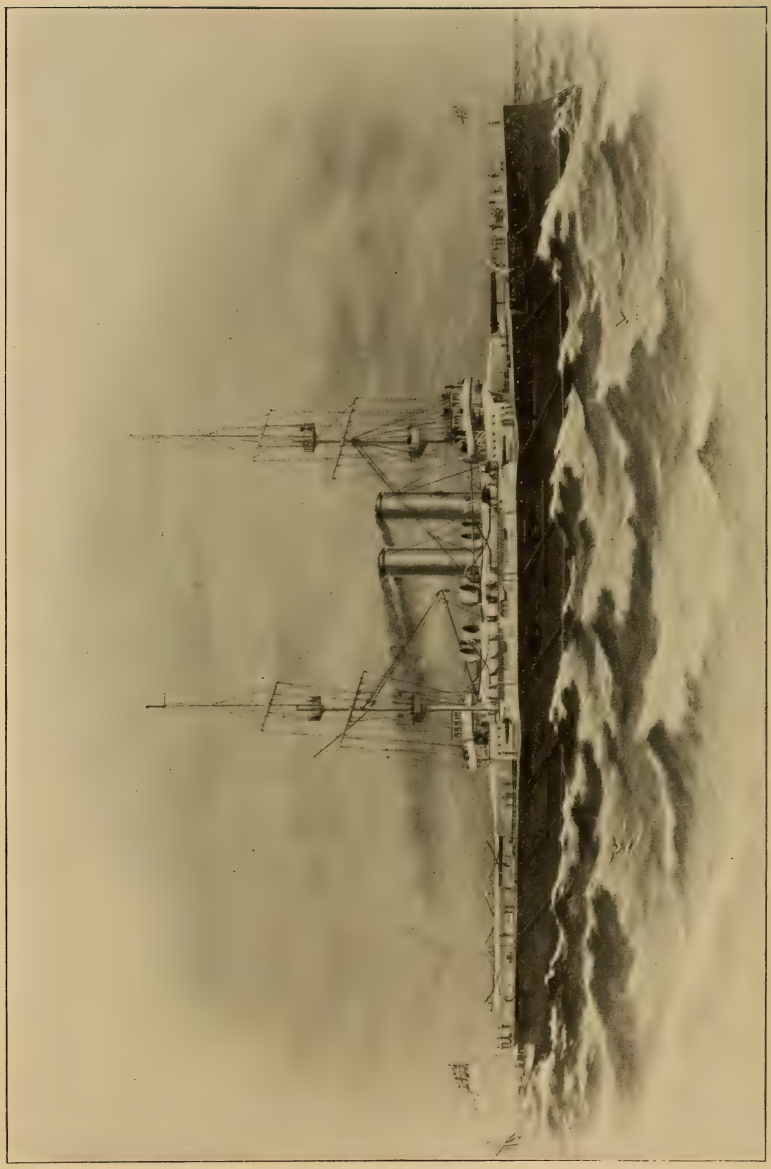

H. M. FIRST-CLASS BATTLESHIP "VENGEANCE." BUILT BY MESSRS. VICKERS, SONS & MAXIM, LTD., BARROW-IN-FURNESS.
LENGTH, 390 FEET. BEAM, 74 FEET. DISPLACEMENT, 13,000 TONS. I. H. P., 13,850. SPEED, 18½ KNOTS

these achievements we have gone back on our record, owing to the shipbuilding dispute of 1897 and other causes, particularly the other causes, as has been pointed out by Mr. Arnold-Forster's committee on delayed shipbuilding. The result is that the latest battleships have taken from three to five years to build. There is, fortunately, a slight tendency towards improvement, but we are still a long way behind the record of ten years ago, and the cost of shipbuilding, as was to be expected, has increased immensely, not all of which increase is accounted for by the rise in the cost of labour and material.

Nevertheless, in spite of all difficulties, the Admiralty have succeeded in giving us an entirely new fleet in the past fourteen years, and the ships dating from before 1889 serve as a useful reserve. It is almost entirely on the vessels constructed since 1889 that the fate of the Empire will depend in case of war, and it is not perhaps supererogatory, while counting the cost as we have already done, to see of what that fleet consists.

Although it has been the custom for First Lords of the Admiralty to urge the virtues of a steady and constant policy in the endeavour, too frequently, to put off the claim for large programmes, as Lord Selborne did in the present year, the shipbuilding in the past fourteen years has been neither steady nor constant, and the same criticism will apply to the whole fifteen years down to the proposals of last March. How erratic the Admiralty have been would probably surprise the authorities at Whitehall themselves.

In the five years covered by the Naval Defence Act, with the additions proposed by Lord Spenser, authority was given for the building of thirteen battleships, eleven first-class cruisers, thirty-two of the second class, and four of the third class. In 1894 came a demand for no less than seven more battleships and six third-class cruisers, while in the following year no armoured ships were ordered; in succeeding years there has been an absence of uniformity in the number of vessels of the larger classes laid down, and the same has been true of the smaller craft. Possibly this irregularity cannot be better shown than by reproducing a portion of a tabular statement which appears in the writer's book, "Naval Efficiency: the War-Readiness of the Fleet," showing the number of battleships and cruisers laid down each year:—

Year	Battleships	Armoured Cruisers	Cruisers 1st	Cruisers 2nd	Cruisers 3rd
(1889-3) Naval Defence Act and additions)	13	--	11	32	4
1894	7	--	--	6	--
1895	--	--	4	4	2
1896	5	.	4	3	6
1897	4	--	--	--	3
1897 Supplementary	--	4	--	--	--
1898	3	4	--	--	--
1898 Supplementary	4	4	--	--	--
1899	2	2	--	1	--
1900	2	6	--	1	--
1901	3	6	--	--	2
1902	2	2	--	--	2
Total for 14 years	45	28	19	47*	19

* One cruiser lost

In addition to these battleships and cruisers we have built or begun 16 sloops (one, the *Condor*, foundered); 136 torpedo-boat destroyers, two of which have been lost at sea; 18 torpedo gunboats, built under the Naval Defence Act and known as "torpedo catchers," being the predecessors of the torpedo-boat destroyers; 23 torpedo-boats; 6 gunboats; and 9 submarines.

The significance of these figures lies in the fact that in this period of fifteen years the construction of battleships has never been less than since Germany decided to spend £86,000,000 in strengthening her fleet, and France reverted to the building of battleships by ordering the laying down of six battleships, besides five armoured cruisers, which are to be completed before January 1, 1907, somewhat over four years from the present date. Both these important measures were passed in the year 1900, and it is in the intervening period and in face of such naval activity in France and Germany that the Admiralty have chosen to ask Parliament for fewer battleships than in any year but one, 1895 (when the pressure of the previous year's remarkable programme was heavy) since the naval revival of 1889. Since

H. M. FIRST-CLASS BATTLESHIP "HOGUE." BUILT BY MESSRS. VICKERS, SONS & MAXIM, LTD., BARROW-IN-FURNESS. LENGTH, 440 FEET. BEAM, 69 FEET. DISPLACEMENT, 12,000 TONS. I. H. P., 21,400. SPEED, 22 KNOTS

1889 we have laid down the same number of battleships each year as Germany, and if we begin, as is proposed, only two battleships this and each future year (and Lord Selborne has suggested this policy by inference) we shall have in 1920 a modern battle fleet only two ships superior to that of Germany. France last year laid down two battleships and has this year authorised the laying down of the last four of her programme.

But the main purpose of this article is to consider the British fleet as it is. Some account must be taken of the ships launched prior to 1889. Although several of the *Admiral* class of battleships, which belong to the period immediately preceding 1889, still figure in the Reserve Squadron, they are obsolescent, and will remain in full commission only until the vessels now building are finished. Of the "New Fleet," as we may call the men-of-war authorised by Parliament in the past fourteen years, thirty-two battleships have been completed; of the twenty-six armoured cruisers, six are at sea; and all the other cruisers, except four of the third class, are complete. If war were to break out to-morrow, it is on these ships mainly that the defence of the Empire would depend, and representing, as they do, the latest development in marine engines of war, it must be admitted that they form a fine navy, of which the nation has reason to be proud.

No other power has a fleet that in any way compares with it, and there is no other power that keeps its ships, year in and year out, so uninterruptedly in commission. The British squadrons, ten in number, are fully manned and at sea, winter and summer, without intermission. The fleet which would be relied upon for the defence of the Empire at the present time comprises completed ships of the various classes given in the table on page 651, the figures in parentheses indicating the year when they were laid down.

In addition, there are a dozen fairly seaworthy battleships over twenty years old, which might prove of some service, and nine armoured cruisers of poor speed, ranging from twenty-one to sixteen years old, of the *Australia* and *Warspite* classes, all of which have been withdrawn from the sea-going squadrons, except two, while three others are serving as gunnery tenders at the home ports.

What is the value of the fleet? According to the Accountant-General, the first cost of the men-of-war completed down to the end of March, 1902, was £111,528,771, and the annual sum which the nation has to set aside each

SIR JOHN COLOMB

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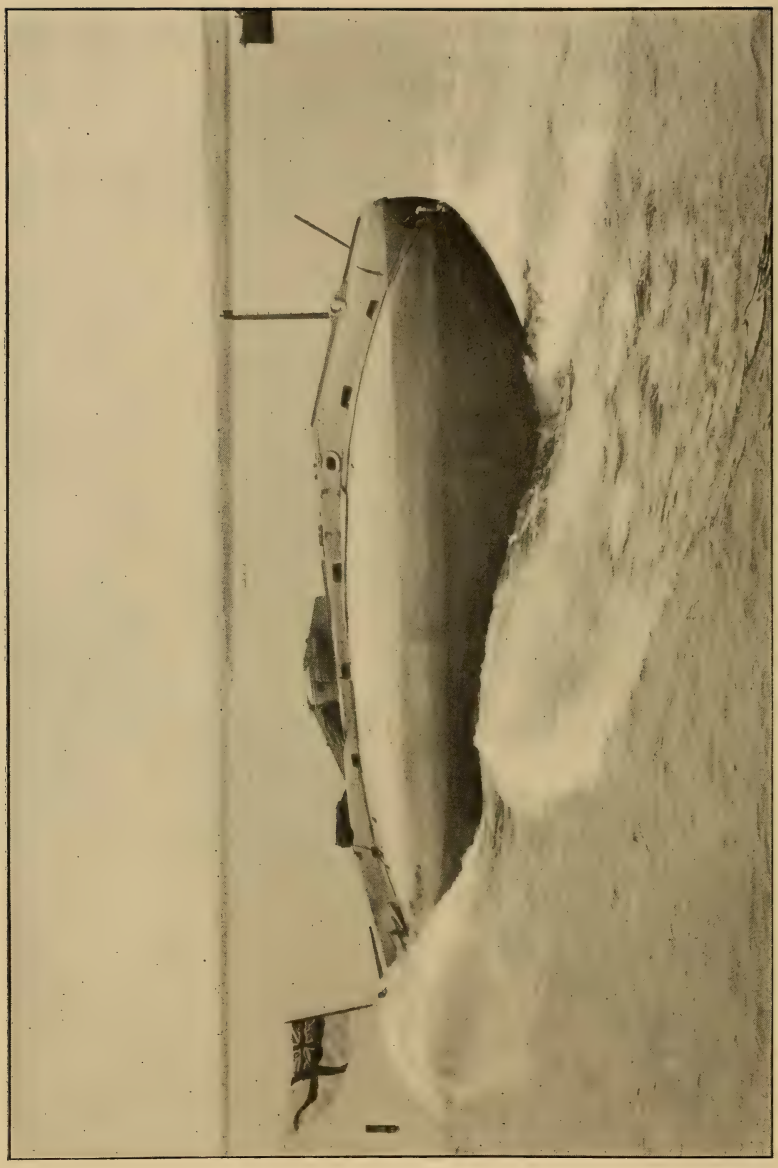
year for making good depreciation amounts to no less than £3,678,836 on the Admiralty calculation, or four-tenths of the total sum set aside for new ships. Besides the ships completed, the vessels under construction on April 1 last will represent, when ready for sea, an additional sum of £32,500,000, so that while the present value of the Navy is £111,500,000 in round figures, its value in 1906, when all the ships now building or authorised will be in the fleet, should be £144,000,000. From this total, however, must be deducted four years'



LAUNCHING A SUBMARINE BOAT FOR THE BRITISH NAVY, AT THE YARD OF MESSRS. VICKERS, SONS & MAXIM, LTD., AT BARROW IN-FURNESS

BY PERMISSION OF THE "NAVY AND ARMY ILLUSTRATED"

depreciation,—a matter of nearly £15,000,000, according to the official tables of depreciation, so that the first cost will be about £129,000,000 in the year 1906.

COMPLETED SHIPS OF THE BRITISH NAVY

BATTLESHIPS

No of ships	Name of Class	Displacement (tons)
6	London (1898)	15,000
9	Majestic (1893-5)	14,900
8	Royal Sovereign (1889-91)	14,150
1	Renown (1893)	12,350
6	Canopus (1895-7)	12,950
2	Centurion & Barfleur (1890-1)	10,500
2	Nile & Trafalgar (1886)	11,940
6	Admiral (1880-2)	10,600
1	Sans Pariel (1885)	10,470
41		

ARMOURED CRUISERS

6	Cressy (1898)	12,000
6		

PROTECTED CRUISERS

2	Powerful & Terrible (1894)	14,200
4	Diadem (1895-6)	11,000
4	Argonaut (1895-7)	11,000
2	Blake & Blenheim (1889)	9,000
4	Crescent (1889-90)	7,700
5	Edgar (1889-90)	7,350
4	Arrogant (1895-6)	5,750
3	Hermes (1897)	5,600
8	Bonaventure (1890)	5,600
8	Phaeton & Thames (1880-4)	4,360
9	Talbot (1893-6)	4,050
10	Pique (1889-95)	3,600
10	Latona (1889-91)	3,400
11	Pandora & Pelorus (1895-7)	2,135
9	Pallas & Wallaroo (1889-91)	2,575
2	Medusa (1887)	2,800
4	Blonde (1887-8)	1,580
2	Bellona (1889)	1,830
2	Pylades (1881-3)	1,440
7	Archer (1885-6) (unprotected)	1,770
2	Scout & Fearless (1885) "	1,580
3	Magicienne (1887)	2,950
115		

22 Sloops
28 Torpedo Vessels
111 Torpedo Boat Destroyers
19 Torpedo Boats
5 Submarines
24 First-class Gunboats

As a matter of fact, battleships cease to be of fighting value before they are twenty-two years old and many cruisers before they have reached the age of fifteen years, but these are the Admiralty standards for depreciation.

The achievement of the past fourteen years has not consisted only in the construction of ships, but in the awakening which has taken place as to the necessity for an organisation that will fit the fleet for war. Something has been accomplished, but a great deal remains to be done before the nation can afford to relax its efforts to obtain a fleet, not on a war footing, but so organised as to be prepared for war. This is the road on which the Admiralty are travelling, if sometimes with halting steps.

We have now a hospital ship, the *Maine*, the torpedo depot ships *Vulcan* and *Hecla*, and several storeships. A distilling ship, the *Acquarius*, has been purchased and prepared for service, as has the steam repair ship *Assistance*, while another depot ship has also been acquired. A number of colliers are already working with the fleet, and a new vessel, the *Muriel*, has been bought and sent to the Mediterranean, to further test her mechanism for coaling men-of-war while they are steaming at sea.

As Lord Selborne has explained, there are two classes of instruments which will be required in time of war,—the class which cannot be improvised and which must be fully created in time of peace, and the class which can be improvised speedily on the outbreak of war if proper preparation has been made in time of peace. This is a wiser policy than to lock up large capital and many men in peace time in non-fighting ships. Certain preparations have been made for improvising additional hospital ships, colliers, telegraph ships and other auxiliaries; but whether these preparations can yet be regarded as deserving to be classed as "proper preparations" is another matter.

It is at least satisfactory that so many new, well-equipped ships (if undergunned in comparison with several of the other Powers) have been built in the past fourteen years, and that a commencement has been made in organising the Navy for its work.

COSTS OF ELECTRIC POWER TRANSMISSION

A PRACTICAL APPLICATION OF PRINCIPLES

By Alton D. Adams

ELECTRICAL transmission of energy involves problems quite distinct from its development. A great water-power, or a location where fuel is cheap, may offer opportunity to generate electrical energy at an exceptionally low rate of cost. This energy may be used so close to the point of its development that the cost of transmission is too small for separate consideration.

An example of conditions where the important problems of transmission are absent exists in the numerous factories grouped about the great water-power plant at Niagara and drawing electrical energy from it. In such a case energy flows directly from the dynamos, driven by water-power, to the lamps, motors, chemical vats, and electric heaters of consumers through the medium, perhaps, of local transformers. Here the costs and losses of transmitting or distributing equipments are minor matters, compared with the development of the energy.

If, now, energy from the water-power is to be transmitted over a distance of many miles, a new set of costs is to be met. In the first place, it will be necessary to raise the voltage of the transmitted energy much above the pressure at the dynamos in order to save in the weight and cost of conductors for the transmission line. This increase of voltage requires transformers with capacity equal to the maximum rate at which energy is to be delivered to the line. These transformers will add to the cost of the energy that they deliver in two ways, by the absorption of some energy to form heat, and by the sum of annual interest, maintenance, and depreciation charges on the price paid for them. Other additions to the cost of energy delivered by the transmission line must be made to cover the annual interest, maintenance, and depreciation charges on the amount of the line investment, and to pay for the energy changed to heat in the line.

Near the points where the energy is to be used, the transmission line must end in transformers to reduce the voltage to a safe figure for local distribution. This second set of transformers will further add to the cost of the delivered energy in the same ways as the former set.

From these facts it is evident that, to warrant an electrical transmission, the value of energy at the point of distribution should at least equal the value at the generating plant, plus the cost of the transmission. Knowing the cost of energy at one end of the transmission line and its value at the other, the difference between these two represents the maximum cost at which the transmission will pay.

Three main factors are concerned in the cost of electric power transmission, namely, the transformers, the pole line, and the wire or conductors. These factors enter into the cost of transmitted energy in very different degrees, according to the circumstances of each case. The maximum and average rates of energy transmission, the total voltage, the percentage of line loss, and the length of the line mainly determine the relative importance of the transform-

ers, pole line, and conductors in the total cost of delivered energy.

First cost of transformers varies directly with the maximum rate of transmission, and is nearly independent of the voltage, the length of the transmission and the percentage of line loss. A pole line changes in first cost with the length of the transmission, but is nearly independent of the other factors. Line conductors, for a fixed maximum percentage of loss, vary in first cost directly with the square of the length of the transmission and with the rate of the transmission; but their first cost decreases as the percentage of line loss increases and as the square of the voltage of transmission increases.

If a given amount of power is to be transmitted, at a certain percentage of loss in the line and at a fixed voltage, over distances of 50, 100, and 200 miles, respectively, the foregoing principles lead to the following conclusions:—The capacity of transformers being fixed by the rate of transmission, will be the same for either distance, and their cost is, therefore, constant. Transformer losses, interest, depreciation, and repairs are also constant. The cost of pole line depending on its length, will be twice as great at 100 and four times as great at 200 as at 50 miles. Interest, depreciation, and repairs will also go up directly with the length of the pole lines.

Line conductors will cost four times as much for the 100 as for the 50-mile transmission, because their weight will be four times as great, and the annual interest and depreciation will go up at the same rate. For the transmission of 200 miles the cost of line conductors and their weight will be sixteen times as great as the cost at 50 miles. It follows that interest, depreciation, and maintenance will be increased sixteen times with the 200-mile transmission over what they were at 50 miles, if voltage and line loss are constant.

A concrete example of the cost of electric power transmission over a given distance will illustrate the practical application of these principles. Let the problem be to deliver electrical energy in a city distant 100 miles from the generating plant! Transformers with approximately twice the capacity corresponding to the maximum rate of transmission must be provided, because one set is required at the generating and another at the delivery station. The cost of these transformers will be approximately \$7.50 (£1.10) per horse-power for any large capacity.

Reliability is of the utmost importance in a great power transmission, and this requires a pole line of the most substantial construction. Such a line in a locality where wooden poles can be had at a moderate price will cost, with conductors in position, about \$500 (£100) per mile, exclusive of the cost of the conductors themselves or of the right of way. The 100 miles of pole line in the present case should, therefore, be set down at a cost of \$50,000 (£10,000).

A large delivery of power must be made to warrant the construction of so long and expensive a line, and 10,000 horse-power may be taken as the maximum rate of delivery. On the basis of two horse-power of transformer capacity for each horse-power of the maximum delivery rate, transformers with a capacity of 20,000 horse-power are necessary for the present transmission. At \$7.50 (£1.10) per horse-power capacity, the first cost of these transformers is \$150,000 (£30,000).

Before the weight and cost of line conductors can be determined, the voltage at which the transmission shall be carried out and the percentage of the energy to be lost in the conductors at periods of maximum load must be decided on. The voltage to be used is a matter of engineering judgment, based, in large part, on experience, and cannot be determined by calculation. In a transmission of 100 miles the cost of conductors is certain to be a very heavy item, and, as this cost decreases as the square of the voltage goes up, it is desirable to push the voltage as high as the requirement for reliable service permits.

A transmission line more than 200 miles long, from the mountains to San Francisco, Cal., has been in constant and successful use for about one year

with 40,000 volts pressure. This line passes through wet as well as dry climate. It seems safe to conclude, therefore, that 40,000 volts may be used in most places with good results.

Having decided on the amount of power and the voltage and length of the transmission, the required weight of conductors will vary inversely as the percentage of energy lost as heat in the line. The best percentage of loss depends on a number of factors, some of which, such as the cost of energy at the generating plant, are peculiar to each case.

As a provisional figure, based, in part, on the practice elsewhere, the loss on the line here considered may be taken at 20 per cent. when transmitting the full load of 10,000 horse-power. If the line is constructed on this basis the percentage of loss will be proportionately less for any smaller load. Thus, when the line is transmitting only 5,000 horse-power, the loss will amount to 10 per cent. During the greater portion of each day the demand for power is certain to be less than the maximum figure, so that a maximum loss of 20 per cent. will correspond to an average loss on all the power delivered to the line of probably less than 15 per cent.

In order to deliver 10,000 horse-power by the transformers at a receiving station from a generating plant 100 miles distant where the pressure is 40,000 volts, the copper conductors must have a weight of nearly 850,000 pounds, if the loss of energy in them is 20 per cent. of the energy delivered to the line. Taking these conductors at a medium price of 15 cents(7½d.) per pound, their cost amounts to $127,500 (£25,500).

The combined cost of the transformers, pole line, and line conductors, as now estimated, amounts to $327,500 (£65,500). To this cost $12,500 (£2500) may be fairly added to provide for transforming stations, switchboards and electric measuring instruments, bringing the total figure up to $340,000 (£68,000). No account is taken of the right of way for the pole line, because in many cases this would cost nothing, the public roads being used for the purpose; in other cases the cost might vary greatly with local conditions.

The efficiency of the transmission is measured by the ratio of the energy delivered by the transformers at the receiving station for local distribution to the energy delivered by the generating plant to the transformers that supply energy to the line for transmission. If worked at full capacity the large transformers here considered would have an efficiency of nearly 98 per cent.; but as they must work, to some extent, on partial loads, the actual efficiency will hardly exceed 97 per cent.

The efficiency of the line conductors rises on partial loads, and may be safely taken at 85 per cent. for all of the energy transmitted, though it is only 80 per cent. on the maximum load. The combined efficiencies of the two sets of transformers and the line give the efficiency of the transmission, which equals the product of $0.97 \times 0.85 \times 0.97$, or almost exactly 80 per cent. In other words, the transformers at the water-power station absorb 1.25 times as much energy as the transformers at the receiving station deliver to distribution lines in the place of use.

Repairs, maintenance, and depreciation of this complete transmission system are sufficiently provided for by an allowance of 10 per cent. yearly on its entire first cost. A further allowance of 5 per cent. on the investment takes care of the yearly interest charge. As the total first cost of the transmission system was found to be $340,000 (£68,000), the annual expense of interest, depreciation, and repairs at 15 per cent. of this sum amounts to $51,000 (£10,200). Management, labour, and incidental expenses in the operation of the system may be fairly set down at $15,000 (£3,000) per year, so that the total expense of operation, apart from the cost of energy, is $66,000 (£13,200) annually.

In order to find the bearing of this annual charge on the cost of power transmission the total amount of energy transmitted annually must be determined. The 10,000 horse-power delivered by the system at the sub-station is

simply the maximum rate at which energy may be supplied, and the element of time must be introduced in order to compute the amount of transmitted energy. If the system could be kept at work during twenty-four hours a day at full capacity, the delivered energy would be represented by the product of the numbers which stand for the capacity and for the total number of hours yearly.

Unfortunately, however, the demands for electric light and power vary through a wide range in the course of each twenty-four hours, and the period of maximum demand extends over only a small part of each day. The problem is, therefore, to find what relation the average load that may be had during the twenty-four hours bears to the capacity required to carry this maximum load. As the answer to this question depends on the power requirements of various classes of consumers, it can be obtained only by experience. It has been found that electric stations, working twenty-four hours daily on mixed loads of lamps and stationary motors, can deliver energy to an amount represented by the necessary maximum capacity during about 2400 hours per year. Applying this rule to the present case, the transformers at the sub-station, if loaded to their maximum capacity of 10,000 horse-power by the heaviest demands of consumers, may be expected to deliver energy to the amount of $2400 \times 10{,}000 = 24{,}000{,}000$ horse-power-hours yearly.

The total cost of operation for this transmission system was found above to be \$66,000 (£13,200) per annum, exclusive of the cost of energy at the generating plant. This sum, divided by 24,000,000, shows the cost of energy transmission to be 0.275 cent (0.137d.) per horse-power-hour, exclusive of the first cost of the energy. On the basis of 3000 hours, the ordinary working time per year, the yearly cost of this transmission is \$8.25 (£1.13.0) per horse-power. To obtain the total cost of transmission, the figures just given must be increased by the value of the energy lost in transformers and in the line conductors. In order to find this value, the cost of energy at the generating plant must be known.

The cost of electrical energy at the switchboard in a water-power station is subject to wide variations, owing to the different investments necessary in the hydraulic work per unit of power developed. With very large powers, such as are here considered, a horse-power-hour of electrical energy may be developed for materially less than 0.5 cent (0.25d.). As the average efficiency of the present transmission has been found to be 80 per cent. of the energy delivered by the generators, it is evident that five horse-power-hours must be drawn from the generators for every four horse-power-hours supplied by the transformers at the sub-station for distribution. In other words, one-fourth horse-power-hour is wasted for each horse-power-hour delivered.

The cost of one-fourth of a horse-power hour, or $0.5 \times 0.25 = 0.125$ cent (0.0625d.), must thus be added to the figures for transmission cost already found, that is, 0.275 cent (0.137d.) per horse-power-hour, to obtain the total cost of transmission. The sum of these two items of cost amounts to $0.275 + 0.125 = 0.4$ cent (0.2d.) per horse-power-hour, as the entire transmission expense. For a working year of 3000 hours the expense of power transmission is thus, $3000 \times 0.4 = \$12$ (£2.8.0) per horse-power. If to this expense per horse-power-hour for transmission is added the cost of energy at the generating station, the total cost of delivered energy is $0.4 + 0.5 = 0.9$ cent (0.45d.) per horse-power-hour, or $0.9 \times 3000 =$ \$27 (£5.8.0) per horse-power for a working year of 3000 hours.

It may now be asked how the cost of transmission just found will increase if the distance be extended. As an illustration, assume the length of the transmission to be 150 instead of 100 miles. Let the amount of energy delivered by the sub-station, the loss in line conductors, and the energy drawn from the generating plant remain the same as before. Evidently the cost of the pole line will be increased 50 per cent., that is,

from $50,000 (£10,000) to $75,000 (£15,000). Transformers, having the same capacity, will not be changed from the previous estimate of $150,000 (£30,000). Sub-station, switchboard, and instruments will also remain at the same cost of $12,500 (£2500). If the voltage of the transmission remain constant, as well as the line loss at maximum load, the weight and cost of copper conductors must increase with the square of the distances of transmission. For 150 miles the weight of copper will thus be 2.25 times the weight required for the 100-mile transmission, or 850,000 × 2.25 = 1,912,500 pounds. At 15 cents (7½d.) per pound, as before, the cost of this copper is $286,875 (£57,375). The complete investment for the transmission system over 150 miles is thus $449,375 (£89,875). Interest, maintenance, and depreciation at 15 per cent. of this sum amount to $67,406 (£13,481) yearly.

As there are now 50 miles more of line to be cared for, the expense of operation may be increased to $16,500 (£2300) yearly, making the total cost of transmission $83,906 (£16,781) per annum, exclusive of the value of lost energy. It was found above that a delivery of 24,000,000 horse-power-hours yearly might fairly be expected from a transmission system with 10,000 horse-power maximum capacity. With this delivery of energy the cost of transmission per horse power-hour is 0.35 cent (0.175d.) nearly, exclusive of the cost of energy lost in the transformers and the line. This loss of energy was found above to be 0.125 cent (0.0625d.) per horse-power-hour of delivered energy, making the total cost of transmission 0.475 cent (0.237d.) per horse power-hour, or $14.25 (£2.17.0) per horse-power per year of 3000 working hours. Adding 0.5 cent (0.25d.) per horse-power-hour as the cost of energy at the generating plant, the total cost of the delivered energy is 0.975 cent (0.487d.) per horse-power-hour, or $29.25 (£5.17.0) per horse-power during a working year of 3000 hours. This last cost is only $2.25 (9 sh.) greater per horse-power-year than that found above for a transmission of 100 miles. It will be noted that the value of the energy lost in this transmission is only 0.125 cent (0.0625d.) per delivered horse-power-hour, while the other expenses, mostly interest, maintenance, and depreciation on the investment, amount to 0.35 cent (0.175d.). The investment in copper could probably be reduced somewhat with advantage, thus raising the amount and cost of energy lost in the line, but reducing the other costs of transmission by a larger amount, so that the total cost would be lowered.

There is another course that promises much better than an increase in the loss assigned to conductors, however, and that course lies in the direction of still higher voltage. The transformers for the two great transmission systems that extend over a distance of about 200 miles, from the Sierra Nevada Mountains to San Francisco, in California, are designed to deliver energy to the line at either 40,000 or 60,000 volts, as desired. Though the regular operation, up to a recent date, has been at the lower pressure, successful experiments have been made with 80,000 volts on the lines, and the intention is to raise the regular working pressure to 60,000 volts as soon as the load increases so that the line loss would be large enough to make the higher voltage desirable.

The lower valleys of the Sacramento and the San Joaquin rivers, which are crossed by these California systems, as well as the shores of San Francisco Bay, have as much annual precipitation and as moist an atmosphere as do most parts of the United States and Canada. There seems to be no good reason, therefore, to prevent the general use of 60,000 volts elsewhere if this pressure proves satisfactory in the parts of California named.

The distance over which energy may be transmitted at a given rate, with a fixed percentage of loss and a constant weight of copper, goes up directly with the voltage employed. This rule follows because, while the weight of conductors to transmit energy at a given rate, with a certain percentage of loss and constant voltage, increases as the

square of the distance, the weight of conductors decreases as the square of the voltage when all the other factors are constant.

Applying these principles to the 150-mile transmission, it is evident that an increase of the voltage to 60,000 will allow the weight of conductors to remain exactly where it was for the transmission of 100 miles, the rate of working and the line loss being equal for the two cases.

The only additional items of expense in the 150-mile transmission, on the basis of 60,000 volts, are the $25,000 (£5000) for pole line and the $1500 (£300) for operating expenses. Allowing 15 per cent. on the $25,000 (£5000) to cover interest, depreciation, and maintenance, as before, gives an item of $3750 (£750), which, plus $1500 (£300) additional operating expense, makes a total yearly increase in the costs of transmission of $5250 (£1050) over that found for the transmission of 100 miles. This last sum amounts to 65.6 cents (2 sh. 7.8d.) per horse-power per year of 3000 working hours when divided up among the 24,000,000 horse-power-hours delivered yearly by the transmission system.

The cost of transmission is thus raised to $12.65 (£2.10.7½) and the total cost of delivered energy to $27.65 (£5.10.7½) per year of 3000 hours on the 150-mile system with 60,000 volts.

FUTURE MARKETS FOR AMERICAN IRON AND STEEL

By Axel Sahlin

One of the most interesting and valuable of recent documents is the elaborate report issued by the British Iron Trade Association and dealing with American industrial conditions and competition. It is based upon the personal observations of a special commission which had been appointed to visit the United States and to enquire into the iron, steel and allied industries. Of this commission Mr. Sahlin was a member, and some of the facts and figures collected by him and conclusions drawn from them are given in the following pages.—THE EDITOR.

At present all the activity displayed in enlarging, rebuilding and in construction of new iron and steel plants has not provided sufficient capacity to fill the demand of a nation growing largely, not only in population, but still more in wealth and industrial development. It is said that the amount of iron and steel consumed per annum per caput of population is a true index of the civilisation of a nation. If this be correct, then America's people stand ahead of all others on the globe, because nowhere else is iron and steel used so lavishly and in so many forms as in the United States. Millions of miles of telegraph and telephone wires, other millions of miles of barbed wire fence, over 200,000 miles of railways with an equipment of over 1,000,000 freight cars and about 40,000 locomotives, steel buildings up to thirty stories in height, thousands of miles of pipe lines sending a steady flow of mineral oil from distant regions to the seaports, or distributing the waters of the mountain streams over the vast stretches of arid plains, and all other staple articles into which the metal is formed, have not only absorbed the whole of America's production of iron, which in the year 1900 amounted to 13,789,242 tons, but a deficiency in the supply had to be filled by importation of German steel.

But the greater the present activity, the more enormous the call for steel in all its various shapes, the greater is also the danger that when this demand falls off, even by a small percentage, this small percentage in the shape of hundreds of thousands of tons of material which must be disposed of, will be thrown on to the markets of the world, and, with the usual American energy, placed in competition with the product of other countries. At first, of course, the neu-

tral and colonial markets will be canvassed; but if the overproduction should fill even these, an aggressive export business of American iron and steel products into Europe must be feared.

It is not likely that any large quantity of American iron will find its way abroad in the shape of pig-iron, except, of course, foundry iron, of which a considerable quantity is coming and more will come, into European markets. But the bulk of American metal will appear in the shape of finished steel. Billets, rails, and shapes, locomotives, cars, bridges, wire nails, tools, plates, and bars are some of the articles which the excellent equipment and large productive capacity of the American shops and works will make it possible to sell at low prices.

COST OF PRODUCTION

When speaking of costs it is, of course, impossible to quote the source of information, but the figures which I give below are, I am confident, *bona-fide*, and were given me by men who are thoroughly familiar with this subject.

Foundry iron is likely to be shipped partly from Eastern furnaces, partly from the South. A large furnace in New Jersey can now manufacture No. 1 foundry iron at a cost of 36 shillings 6 pence ($9.12) per ton. The freight rate to New York is, for ordinary business, 2 shillings (50 cents) and somewhat less for export. From New York to Liverpool freights for pig-iron vary from 6 shillings ($1.50) to 12 shillings ($3) per ton. No. 1 foundry iron might, therefore, at the present time be delivered in Liverpool at from 44 shillings 6 pence ($11.12) to 50 shillings 6 pence ($12.62) per ton, not allowing for profit.

At Birmingham, Ala., foundry iron to-day is costing about 37 shillings 6 pence ($9.37) per ton. This iron is produced in old-fashioned furnaces with heavy coke consumption, expensive labour and small output. Mr. Don Bacon, the recently elected chairman of the Tennessee Coal, Iron & Railroad Company, has been publicly quoted as saying that he expects to bring down the cost of foundry iron in this district to 25 shillings ($6.25) per ton. From Birmingham the iron would be shipped to one of the following five ports:—

	Miles.
New Orleans, La.	417
Brunswick, Ga.	448
Savannah, Ga.	448
Mobile, Ala.	276
Pensacola, Fla.	255

The railway freight for export from Birmingham to either of these places is, to-day, 5 shillings 10 pence ($1.45) per ton. The sea transport for iron carried as ballast in cotton ships to Manchester is 8 shillings ($2) per ton. Southern foundry iron can, therefore, to-day be delivered in ship in Manchester at a cost of 51 shillings 4 pence ($12.83) per ton; but if the prediction of the head of the leading Southern iron company should be verified (and there is no question but what costs in the South will be rapidly reduced), Southern foundry iron laid down in Manchester may before long cost as little as 38 shillings 10 pence ($9.70) per ton. How far panic prices of labour, machinery, fuel and freights will tend further to reduce these figures remains to be seen.

The North will not compete abroad with pig-iron. At present Bessemer iron in the Ohio valleys or at Wheeling is said to cost 45 shillings 10 pence ($11.45) per ton. The lowest average converting costs may be taken at 16 shillings 8 pence ($4.16). Steel billets in the Wheeling district do, therefore, at present cost 62 shillings 6 pence ($15.62) per ton. In times of low prices iron has, however, been made for 34 shillings 4 pence ($8.58), and conversion into steel has actually been accomplished for 15 shillings ($3.75) per ton. The lowest possible cost for billets in the Wheeling district may, therefore, be estimated at about 49 shillings 4 pence ($12.33) per ton, or, say, 50 shillings ($12.50). The ordinary freight rate from Wheeling or Pittsburgh to Baltimore is 6 shillings 3 pence ($1.56) per ton, but has for export business been as low as 4 shillings 8 pence ($1.16). Ocean freight has varied from 6 shillings ($1.50) to 12 shillings ($3). Assuming the average freight at 10 shillings ($2.50) per ton, to which figure the Americans confidently expect to bring

it down, when having their own ships, steel billets could at the present high prices be laid down in Liverpool at a cost of 78 shillings 9 pence ($19.68); but if times go down, they may be expected to arrive at a cost of about 64 shillings 8 pence ($13.66) per ton. It must be borne in mind that the costs quoted above are based on market price of raw materials, but as most of the large steel producers control their own ore, fuel and flux, the cost to producers cannot be ascertained, but must be less than the prices named above.

MARKETING A SURPLUS

In an interview, Charles M. Schwab made the statement that his policy would be to keep the plants of the United States Steel Corporation going at their full output, which, at their present rate of production, represents about 9,000,000 tons of steel per year. "We will sell all we can at home," he said; "what we cannot sell at home we will find a market for abroad, and we will rather sell at a slight loss than curtail our production." The wisdom of this policy from an American point of view cannot be doubted. The men who wield the destiny of two-thirds of the most important industry in the largest industrial country in the world have in their hands an incalculable power for good or evil. A sudden move on their part toward curtailing production would at once throw the iron business and all kindred industries into a panic. The United States Steel Corporation support, in supplying the wants of their works, hundreds of other plants,—engine and boiler manufacturers, makers of paints, oils and other lubricants, pipe fittings, tools, brass goods, lumber, brick, cement, stationery, chemicals, instruments, and what not. As long as the works of the corporation keep going apace, taking their usual supplies, all these industries and their hundreds of thousands of employees will be kept in activity. A sudden retrenchment or partial stoppage on the part of the giant corporation would immediately throw them all into partial idleness and create widespread financial distrust and distress. While unchecked and unlimited competition in the iron industry was the order of the day in America such sudden stoppages did come periodically and with scant warning, causing great and unexpected fluctuations in prices and changes in economic conditions. It is to be hoped, and many believe, that the Steel Corporation will make the world their debtor by using their great influence in their own interests as in that of others, to prevent and minimise these sudden fluctuations.

From our point of view in England, on the other hand, this policy certainly carries with it great menace. The Steel Corporation control a practically unlimited capital and the best mines, the best coke, the best plants, the best lines of communication, the ablest managers, and the most perfect selling arrangements. When this great syndicate deliberately decide to sell a certain small percentage of their enormous output at cost, or even at a loss, in our own territory, such an action will be apt to demoralise our prices and to send us through such a period of reorganisation, failures and destruction of capital as America experienced in the long to be remembered years between 1893 and 1897. But as America during these years, after learning the dearly bought lesson, pulled itself together and created the present successful organisation of its iron and steel business, so, I have no doubt, will Great Britain do.

BRITISH PROSPECTS

There is no point in the world that need teach Middlesborough a lesson in the cheap production of iron and steel. The Durham coke, if properly made, is equally good, if not better, than that of Connellsville. The collieries and coke ovens are nearer to the Tees than is Connellsville to Pittsburgh. The Cleveland hills yet contain a goodly store of iron ore, if also the grade is going down. To enrich the mixtures the Scandinavian mines, considerably nearer to Middlesborough than are the Lake Superior fields to Pittsburgh, supply an even richer and better raw material. In the opposite direction Spanish hematites are

available with easier transport than that of the Lake ores. Middlesborough has also the advantage over Pittsburgh of being located on the sea and in the midst of the densely populated European countries. If, therefore, the Middlesborough ironmasters adapt,—not copy,—American methods, not only as regards furnace plants and steel works, but also, and of still more importance, as regards generous employment of money, consolidation of interests, control of raw materials, selection of managers, and treatment and control of labour, they should never need fear competition from an industrial centre situated 3,500 miles away from the markets at their very door, and this opinion, I take it, will also hold good for South Wales, the Midland districts and Scotland.

Nor does the world stand still while the iron industry is growing and developing. New markets, new employments, new needs arise and multiply, and, therefore, it is, in my opinion, certain that there will be room for us all in the future, as in the past, though the preponderating influence in the iron world, and the largest outputs of iron and steel, counting by nations, will during this and the next generation continue to be found on the western side of the Atlantic Ocean.

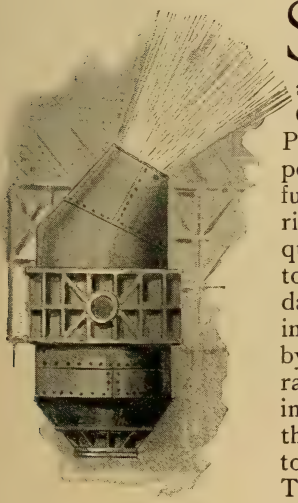
It is an axiom that no nation can remain or become a world power without the aid of an adequate iron industry. Great Britain cannot, and, I am sure, will not see its iron industry permanently lose ground. If, therefore, which I do not believe, it should come to pass that protected America to such an extent makes free-trade Britain the market for such a surplus of iron and steel products as cannot elsewhere be disposed of that the home industry of the latter country seriously and permanently suffers thereby, it must be remembered that nothing but the will and dictum of the British people keeps the door open for such imports, and that it is practicable, if not to close the door, at least to place such a barrier across it as to give those inside a chance to live.

PROGRESS IN THE METALLURGY OF IRON AND STEEL

ESPECIALLY IN THE OPEN-HEARTH PROCESS SINCE 1889

By Henry M. Howe

Professor Howe's admirable review of recent progress in the metallurgy of iron and steel, given in the following pages, was prepared originally for the International Congress on Mining and Metallurgy at Paris in 1900. It was, however, subsequently rewritten in part by the author, for its special use here.—THE EDITOR.



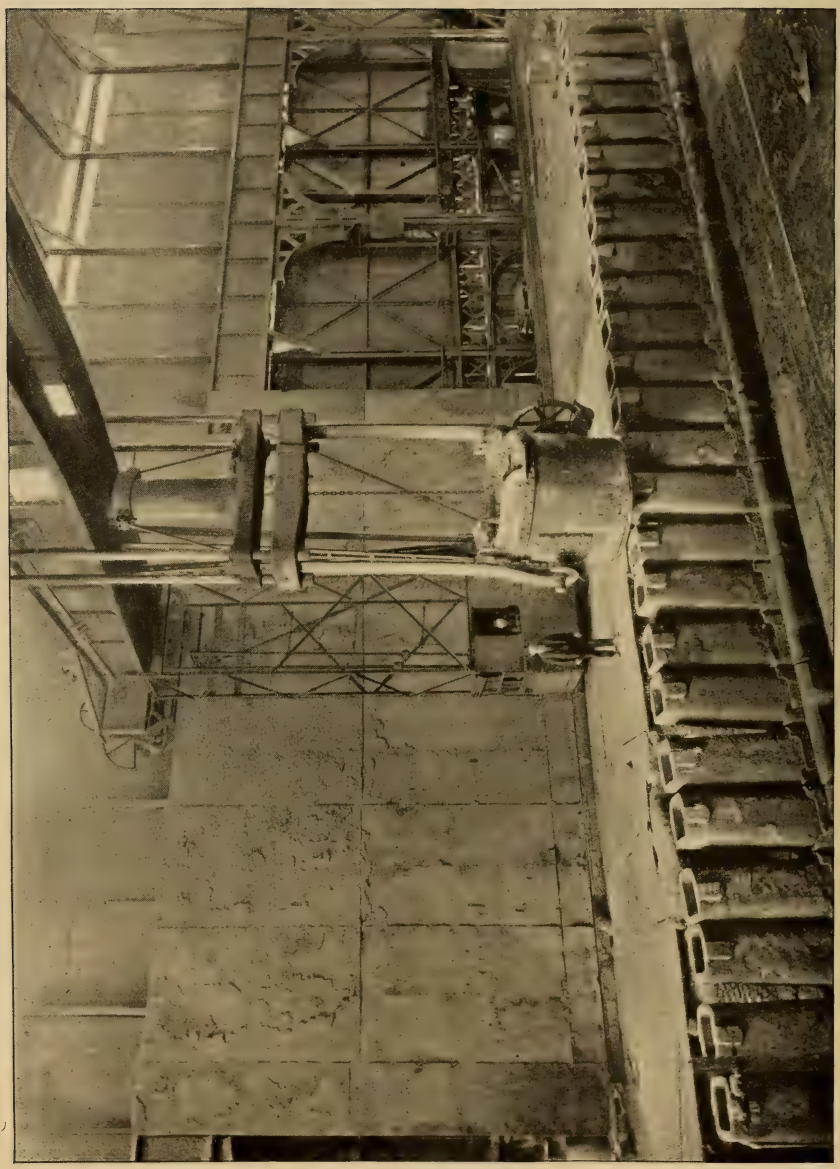
SINCE the time of the International Mining and Metallurgical Congress, held at Paris during the Exposition of 1889, blast-furnace outputs have risen to the enormous quantity of about 600 tons per furnace per day, and a great saving has been effected by mechanical arrangements for casting and for breaking the pigs of cast iron to convenient size. This great increase in the output has been brought about chiefly by enlarging the diameter of the furnace crucible,—a thing manifestly necessary, since we can hardly expect to burn advantageously more than a fixed quantity of coke per square foot of hearth per second,—and by providing extremely powerful blowing engines.

In America this great increase in output took place at the time when American engineers were learning to use the very cheap but extremely fine Mesabi ores; but, fortunately, the two things went well together. A great difficulty in the use of this ore, which in many important cases forms about a third of the ore used, is the formation of scaffolds, leading, in turn, to slips and serious explosions, and a powerful blowing engine is an excellent weapon with which to fight an incipient scaffold. It may here be added that the importance of the utilisation of blast-furnace gases for gas engines can hardly be overestimated.

In the puddling process no striking change has occurred, though it is interesting to note that this process, which has been so often and so long condemned to speedy extinction, has still such vitality that many new hand-puddling furnaces have been built for providing material for the crucible process, and for use as a material for this same process, puddled steel,—an almost forgotten substance—is again made to-day.

In the crucible process no change worthy of mention here has occurred, unless it be that, thanks to the deterioration and high price of the Ceylon graphite, steps have been taken to adopt clay crucibles in place of the graphite crucibles hitherto used almost exclusively in America.

In the Bessemer process we find little change. The use of small converters, such as the Robert and the Tropenas, for making steel castings has continued, and has strong advocates; for although, because of their great waste of iron by oxidation, often reaching 20 or even 25 per cent., the molten steel probably costs more than if made by the open-hearth process, yet it is so much hotter than in the open-hearth furnace that, in making small castings, fewer of them are lost through failure to fill the moulds thoroughly. And since the



THE CAR CASTING SYSTEM AT THE MARYLAND STEEL COMPANY'S WORKS AT SPARROW'S POINT, MARYLAND, U. S. A.

moulding and machining of small castings cost much more than the molten metal, this advantage of the little Bessemer converter may well make it the more economical process of the two.

In large Bessemer works there has been a still further increase of output, and a considerable saving in the cost of manufacture, by the introduction of the "car-casting" system, in which the moulds receiving the molten steel stand on a train of cars, and are carried away from the converting room to the heating or soaking furnaces as soon as they have received the steel. This system not only lessens the number of handlings of both moulds and ingots by one half, which is a serious thing when 1000 white-hot, two-ton ingots and 1000 great, hot moulds have to be handled every twenty-four hours, but it also removes all these exothermic handlings from the converting room, which they formerly made unfit for human habitation through the enormous volumes of heat which they there radiated, and it transfers them to places where the heat radiated from the ingots and moulds causes little inconvenience to the workmen.

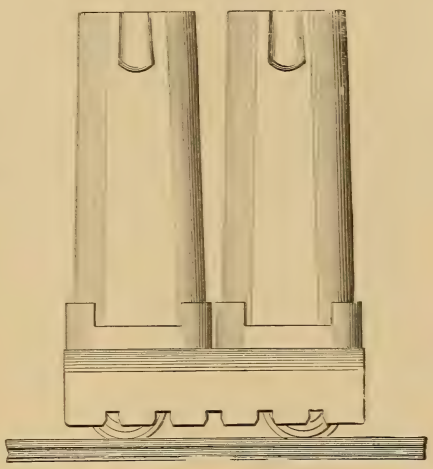
Operating in this way, 2289 tons of ingots, or 239 charges, have been made at Duquesne, Pa., in a pair of ten-ton converters in twenty-four hours, which is at the rate of a charge every six minutes for the entire period; indeed, this output was maintained practically for a whole week, during which 1330 charges, or 12,735 tons of ingots, were made.

In 52 turns in the month of March 1902, the South Chicago (Illinois) Bessemer works, with three 10-ton converters, made 80,481 tons of steel ingots, or at the rate of 3,094 tons per 24 hours, or at about the rate of a charge every five minutes for the whole month.

In the older or "pit-casting" system the steel was poured into large ingot moulds standing in a deep casting pit. When these ingots had solidified slightly, the moulds were removed from them and set on the floor of the converting room. The ingots were then raised, one by one, set upon cars, and carried away to the heating or "soaking" furnaces, while the moulds were replaced in the casting pit to receive a new lot of steel.

Thus each mould had to be handled twice, once in removing it from its ingot, and once in replacing it in the casting pit. Each ingot also had to be handled twice, once in transferring it from the casting pit to the car which carried it to the soaking furnace, and once from this car into that furnace.

Moreover, the moulds remained in the converting room all the time, radiating heat rapidly into it; and the ingots remained in it (1) till cool enough to be lifted out of the casting pit, and (2) until a carload of white-hot ingots



ONE OF THE INGOT TRUCKS

had been there assembled to be removed to the soaking furnaces. The heat radiated from the moulds and ingots jointly was, in summer, almost insupportable.

In the "car-casting" system, devised by Mr. F. W. Wood, president of the Maryland Steel Company, the ingot moulds, while receiving the molten steel, stand upon a train of cars, and are removed immediately, with the ingots still within them, to the side of the soaking furnace in another building. When the train which carries them reaches the soaking furnace it finds another, but empty, train, standing close

beside it on a parallel track. At one motion of a crane two moulds are removed from two ingots and immediately set down on this waiting train, which carries them to the mould-cooling yard, whence they return, when cool, to the converting room. Meanwhile, the ingots thus laid bare are charged by another crane into the soaking furnace direct from the train of cars which brought them.

There is thus only one handling for each mould, from one car to another adjoining it; and only one handling for each ingot, direct from its car into the soaking furnace. Moreover, the white hot ingot stays uncovered but a few seconds, and all these exothermic operations are removed from the converting room to relatively harmless positions.

The basic Bessemer process can hardly be said to have gained a foothold in America, for there is at present in the United States no ready supply of ore yielding pig-iron rich enough in phosphorus to supply the heat needed for the process. One cannot here, as in the common or acid Bessemer process, rely upon the oxidation of the silicon of the cast iron to generate the exalted temperature needed, because the resultant silica would both attack the basic lining of the converter and, by acidifying the slag, interfere with the removal of phosphorus; hence, phosphorus must be relied upon as the calorific agent

It may be well to mention a way of turning the difficulty which, in the absence of sufficiently phosphoric pig-iron, the writer has proposed. When the acid Bessemer process is carried on in the rapid American way, the operation in one converter beginning at the instant at which the operation in the adjoining converter ends, so that charge succeeds charge at intervals of perhaps ten minutes all day long, so little of the heat generated is lost by radiation that much less silicon (the heat-generating element of the pig-iron) is needed than in European practice. Under these conditions 0.80 per cent. of silicon yields all the heat actually needed, or hardly more than one-third of the silicon used in many European works. This low-silicon practice has extended much in America, and it would extend even much farther but for the difficulty of making in the blast furnace cast iron so low in silicon and at the same time sufficiently free from sulphur.

Just as it has been found quite easy in the acid Bessemer process with the rapid American working to get along with much less silicon than is required in the more leisurely European practice, so the writer believes it may be found possible, by carrying on the basic Bessemer process with like rapidity, to get heat enough from a much smaller quantity of phosphorus than has been found necessary in Europe; and for the basic Bessemer process as thus conducted some of the American ores, especially those of the Southern States, may yet be found suitable.

Important as are some of the advances which the writer has thus outlined, we may question whether they equal in importance those which have taken place in the open-hearth process. These call to mind Holley's prophetic words,— "The open-hearth will be at the Bessemer's funeral." "Le Martin assistera aux funerailles du Bessemer." Among the salient features may be noticed,—

1.—A great increase in the size of the furnaces;

2.—A great extension in the use of mechanical charging apparatus;

3.—The rapid growth of the basic open-hearth process, which has, in general, restricted the use of the acid open-hearth to the manufacture of special high-quality steel;

4.—Greater rapidity of working;

5.—Delivering the molten steel even from much larger furnaces, in smaller quantities and at shorter intervals;

6.—The introduction of tilting, barrel-shaped furnaces.

Larger Furnaces.—Fifty-ton furnaces are now common. There is a 75 ton furnace at Pencoyd, Pa., and furnaces to hold 125 and even 200 tons are projected. The cost per ton of product should naturally decrease with the size of the furnace and the consequent increase of output.

Mechanical Charging Apparatus.—The Wellman type of charging machine is so well known that any description suitable for the scale of the present note would be out of place. Suffice it to say that whereas in the older method of hand-charging the scrap iron and pig-iron, after being brought to the side of the furnace, were thrown in, piece by piece, by hand, keeping the furnace doors open while the costly, high-temperature heat poured out, not only wasting itself, but scorching the bodies of the workmen, in the mechanical method the metal is handled but once, in the stock-yard, where it is packed in the cool and at leisure in large boxes, carried on cars to the furnace, and there rapidly charged mechanically into it, while the workmen are not exposed even to the minimum outflow and loss of heat which now occur.

Increased Rapidity of Working.—When, as in Westphalia, the charge in the open-hearth furnace consists chiefly of scrap iron, the operation proceeds very rapidly, so that four or even six charges may be made in twenty four hours. This is hardly astonishing, because the scrap iron contains so little carbon that by the time the charge is molten and hot enough for casting the decarburisation is already nearly complete.

But where pig-iron must form a large part of the charge, the open-hearth process has, until lately, been at a great disadvantage on account of its small output. The charge when first melted down still contains much carbon; and the decarburisation by the oxidising action of iron ore now charged into the furnace cannot be rapid, lest the resultant evolution of carbonic oxide should cause so great a frothing that the slag and metal boil out of the doors of the furnace, or even into the ports. Hence, when the charges consist of pig-iron alone, (pig-and-ore process), only about seven charges can be made per week; and when, as in American practice, they consist of about equal parts of pig-iron and scrap (pig-and-scrap process), only about fourteen charges per week are made. When contrasted with the Bessemer process, in which as many as one hundred charges can be made per converter per twenty-four hours, this is, indeed, a sluggish gait.

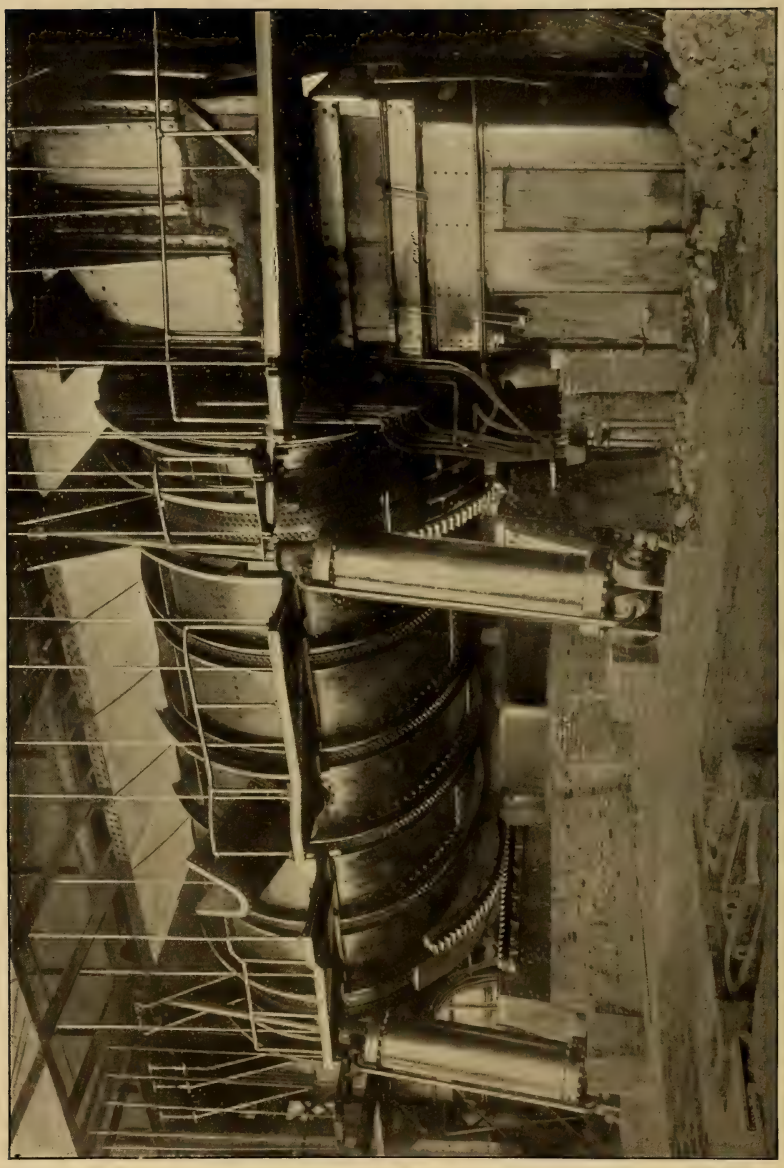
The output per furnace has been nearly quadrupled by the Bertrand-Thiel* process, even under unfavourable conditions. This process uses two basic open-hearth furnaces, a small upper one in which pig or cast iron is melted and partly refined, and a larger lower one in which all the scrap available, together with the rest of the cast iron and some iron ore, are heated nearly to melting.

The partly refined charge from the upper furnace is then run upon the charge in the lower furnace, when the two react with extremely rapid purification, *i. e.*, oxidation of the carbon, silicon and phosphorus. As soon as the charge is sufficiently purified, the final additions are made and the metal is tapped into ingot moulds in the usual way.

The rapidity of the process seems to be due to more rapid purification. Why, then, is the purification so rapid? To fix our ideas, let us confine our attention to the removal of a single element, carbon, premising that the chemical work of the open-hearth process, the purification of the metal by the removal of its carbon, silicon, and phosphorus, is brought about chiefly by oxidising these substances by means of iron oxide, for when oxidised they remove themselves bodily from the molten iron.

In common open-hearth practice the rapidity of decarburisation is limited by the danger that the slag may froth over and run out of the doors and into the ports, since the carbon is removed in the form of a gas,—carbonic oxide,—and since the escape of a gas from within a liquid mass always must cause boiling, if not frothing. But why is the permissible rapidity greater in the Bertrand-Thiel than in common open-hearth working? And, if the permissible speed limit be thus raised, why is the

* Transactions American Institute of Mining Engineers, Washington meeting, February, 1900.—The writer's remarks on the Bertrand-Thiel process have been rewritten in the light of his recent study of the process at Mr. Bertrand's works.



A WELLMAN ROLLING FURNACE
SEE PAGE 669

actual speed increased? For the actual greater rapidity three reasons present themselves:—

1.—The rapidity per square foot of hearth area is increased by the fact that in a given furnace there is more room for metal, because there is less slag, that of the upper furnace having been diverted, and that made in the lower furnace being, in large part, due to the gangueless, and hence non-slag-making, oxide of iron, which, during the heating up of the scrap iron in the lower furnace has formed upon the surface of the pieces of scrap, instead of to iron ore, the gangue of which, in common open-hearth working, forms slag.

2.—In common open-hearth practice the oxidation of the carbon of the molten bath takes place only at its upper surface, where it comes in contact with the overlying slag and with the lumps of iron ore which float in that slag, while in the Bertrand-Thiel process this oxidation takes place throughout the depth of the molten mass. When the molten pig-iron from the upper furnace, *i. e.*, that part of the charge which contains carbon, is run upon the white-hot scrap in the lower furnace, the whole surface of each piece of that scrap is thickly coated with a layer of iron oxide near its melting point. Thus, for each bar or rod of scrap, there is an envelope of plastic iron oxide submerged in the molten cast iron, which in this way is penetrated through and through by these iron oxide envelopes or shells, already nearly melted, and thus in a position to react with very great rapidity, both from their temperature and from the extent of surface which they offer to the molten cast iron.

Contrast this with the condition in common open-hearth work, in which the reaction between the cast iron and the iron oxide takes place only at the upper surface of the metal, which, as well as the slag with which it reacts, is there locally chilled and made viscous by the cold lumps of iron ore thrown in. To this viscosity I will shortly return. Beyond this the outer layers of the scrap are probably oxygenated to a considerable extent; they alloy with the molten cast iron, and coalesce with it, so that the oxygen of one is in excellent condition to react rapidly on the carbon of the other. The temperature is higher, both because (as just explained) the carbon, silicon, and phosphorus are oxidised faster, and also because the two reacting bodies, semi-refined cast iron and oxygenated steel scrap, are initially very hot, while in the common open hearth process the reaction takes place between the carbon of the metal locally cooled, and cold ore.

Since the above was written Mr. Bertrand has applied his process with success to molten pig iron alone without scrap. An analysis of the process under these conditions remains to be made.

But why does not this faster decarburisation cause excessive frothing? Frothing depends on viscosity. Your cook beats eggs or cream easily into froth, but not water or alcohol. The slag, because more viscid than the metal, is the chief frother. Now the frothing, even with the faster decarburisation of the Bertrand-Thiel process, is not excessive, because there is less slag to froth; the slag is hotter, and hence more liquid; the charge as a whole is hotter; and finally because the slag is not, as in common practice, chilled just where the carbonic oxide is evolved by the cold ore floating upon it.

Delivering the Steel in Smaller Quantities.—To lessen the reproach against the open-hearth process that its production is so small, larger and larger furnaces have been made. But when we are making rails or plates it is extremely inconvenient to have the molten steel delivered thus at long intervals in enormous lots of fifty or seventy-five tons; here the Bessemer process has the great advantage of delivering relatively small quantities of, say, ten tons each at short intervals of, say, ten or fifteen minutes.

This inconvenience is lessened by the very promising, continuous, basic open-hearth process devised and perfected by Mr. Benjamin Talbot, of Middlesbrough, England. Instead of, as

in common practice, treating each charge as a distinct individual entity, tapping it as a whole from the furnace, Mr. Talbot taps from the tilting Wellman furnace at relatively short intervals about one-quarter of the charge, immediately replacing it with fresh molten pig-iron, which is thus at once lost in the bath already present. After a few hours more, again one quarter of the bath is tapped out, and again an equivalent quantity of new pig-iron is poured in; and so the process goes on without emptying the furnace or materially changing its temperature throughout the whole week.

In addition to the advantage of delivering the steel from a large furnace in small manageable lots, this process has a further advantage in avoiding the difficulties which in common, intermittent practice arise during the melting down of each successive charge. These difficulties are:—

1.—The low temperature and the conditions of exposure during melting favour the oxidation of iron and silicon, with the formation of a relatively silicious and ferruginous, and hence corrosive, slag, which attacks the furnace in its most vulnerable condition, before it has become covered with a protective coating of molten metal. It is this period, when the slag is temporarily ferruginous and silicious, that is most trying to the now unprotected bottom and to the sides.

2.—If for any reason we are later unable to get as high a temperature as is desirable, we may have difficulty in again deoxidising the iron thus initially oxidised.

3.—At this low temperature during, and shortly after, melting down, decarburisation is necessarily slow. It cannot become rapid until the temperature has risen high, *i. e.*, until after a considerable length of time.

Since in the continuous process there is but one melting down each week, these troubles arise only once, instead of with every charge. Each charge, except the first, finds the furnace nearly full of molten metal, which protects the bottom. The iron, even if it be scrap, does not oxidise much, because it is at once plunged beneath this molten bath; the silica which results from the oxidation of the silicon finds a large mass of basic slag still present to dilute it, so that we have neither the temporarily silicious and ferruginous slag nor the exposure of the bottom to the attack of the slag, which are encountered in the intermittent process. On this account Mr. Talbot is able to raise the limit of silicon in his pig-iron from the habitual trade limit of 1 per cent. to 1.50 per cent.—in itself a great advantage, since a much larger proportion of the pig-iron made by a given blast-furnace will naturally be acceptable. Indeed, he can at present make a large saving by buying the "misfit" pig iron of the market.

Finally, thanks to the great fly-wheel of heat in the residual bath which each new charge meets in the furnace, the temperature is almost immediately high enough for very rapid decarburisation.

From this last fact we might expect that the production, measured in furnacefuls, would be much greater than in the common intermittent practice. But, perhaps for a reason which I will shortly give, it is not. When treating pig-iron alone without scrap the output of a 75-ton Talbot furnace, per week of 138 hours, is about 500 tons of steel, which, though tapped out in, say, twenty-five lots of 20 tons each, is really equal to only about seven furnacefuls of 75 tons each.

Seven furnacefuls per week are but little above the usual output of the intermittent open-hearth process under the same conditions, *i. e.*, when treating pig-iron without scrap. To be sure, Mr. Talbot's furnacefuls are unusually large per square foot of hearth. One reason for this is evident. Before the charge is tapped from the furnace it must be carefully adjusted, *i. e.*, brought simultaneously to the right temperature and composition. This adjustment takes considerable time. Now, since only one-fourth of a furnaceful is tapped at one time, and since for every tapping time must be taken for this adjustment, we have four adjustments per furnace-

ul of steel instead of one, as in intermittent practic. One naturally fears that this week-long exposure to high temperature without the cooling-off which, in the intermittent practice, occurs every few hours, would shorten the life of roof and bottom. But, as regards the bottom, experience thus far indicates strongly that this consideration is outweighed by the advantage which the continuous process has in avoiding the attack of the silicious and ferruginous slag upon the unprotected bottom when first melting down. As regards the roof, further experience alone can show whether the continuity of this exposure to heat, without intervals of relief between charges, is not more trying than the racking effect of the alternate expansion and contraction due to the great alternations of temperature in the intermittent process.*

To sum up, the Bertrand-Thiel process increases the output greatly by its reaction throughout the mass instead of at its surface only; the continuous process draws steel from enormous furnaces in manageable quantities and at convenient intervals, and raises the silicon limit of the pig-iron. No reason appears why these two processes should not be combined, both the upper and the lower Bertrand-Thiel furnaces working on Mr. Talbot's continuous system. This should combine the advantages of both systems.

Rotary Furnaces.—Fifty-ton furnaces of both the Campbell and Wellman types have come into extended use, and have given excellent results. They are of the shape of a barrel lying with its axis horizontal, and rotate nearly or exactly about this axis. They almost completely remove the tap-hole difficulties, and prolong the life of the bottom by permitting the furnace to be emptied more completely, so that but little iron remains behind to oxidise between heats and bore down into the bottom. The Campbell furnace, moreover, permits faster decarburisation, with its consequent greater frothing, because, by tipping it slightly, we raise the level of the charging doors and thus prevent the slag from frothing out of them. In the view of the Wellman rolling furnace on page 666, the furnace itself is the long horizontal cylinder resting upon a pair of racks and rolling on them by means of segments of an enormous pinion. This rolling motion is given to it by large, nearly vertical hydraulic cylinders. The tapping spout is shown in approximately its normal position while the charge is melting and under further preparation, *i. e.*, coming to composition and temperature proper for tapping. In order to tap the metal out of the furnace, the latter itself is rolled toward the left, thus depressing the tapping spout and pouring the molten metal out through it. A suspended platform affords access to the tapping spout.

The Duplex Process.—This process, in which the pig is desilicified in an acid converter and immediately dephosphorised and decarburised in a basic open-hearth furnace, has made some progress, particularly in the hands of Messrs. Daelen and Pszczolka, who have devised a converter especially adapted to it, and use in it the hot blast generated by the plant of the blast furnaces. This certainly is a process from which much may be expected, for it should in great part both retain the merits of the Bessemer process (its small fuel consumption and its rapidity) and avoid its defects,—its great loss of iron and the alleged inferiority of its product to that of the open-hearth process.

While it is yet too early to speak with confidence of the possibilities of this process, we may note that, on one hand, the actual loss is even higher than in the normal acid Bessemer practice,—13.8 per cent.,—and that, on other hand, the merits of the process have induced some establishments to adopt it, as Mr. Daelen has informed the writer.

* The writer has since become connected with litigation touching Mr. Talbot, and he is therefore prevented from modifying his original language. For the same reason he refrains from adding any reference to the Monell open hearth process in use at the Homestead works of the Carnegie Steel Company.

AUTOMOBILES FOR WAR SERVICE

By Brigadier-General J. H. A. Macdonald

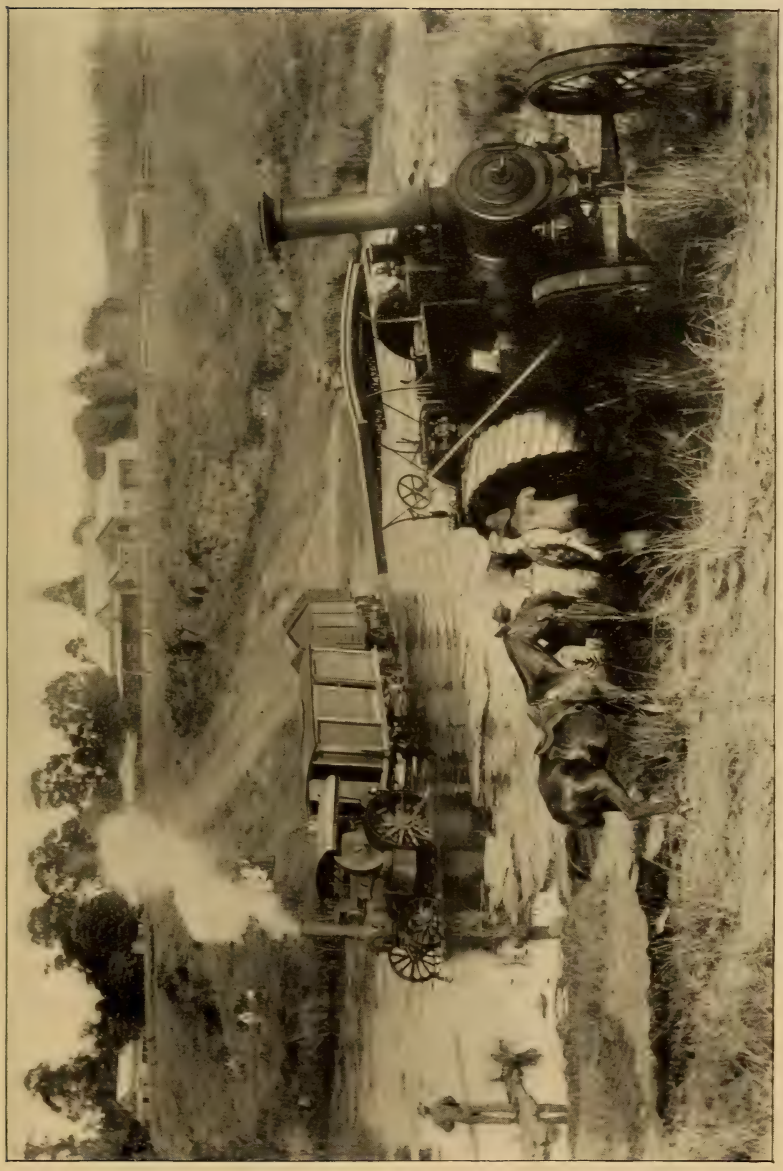
CUGNOT'S CONCEPTION, IN 1769, OF USING A STEAM CARRIAGE FOR HAULING ARTILLERY

WITH war as a factor in national life, brought home to Great Britain particularly by the late conflict in South Africa, the question of the applicability of power traction to military purposes should be studied carefully, and that without delay. It was with the desire to stimulate such study among those engaged in power traction enterprise that the writer, a short time ago, brought the subject before the Automobile Club of Great Britain and Ireland.

There are two aspects, as he stated in his discourse at that time, in which the matter presents itself,—the combatant and the non-combatant. Both are important. The first relates to the uses which can be made of power traction to move weapons of war to and within the area of actual fight, and to carry armed men into or out of that area, and, it may be, to give them practical aid and protection while fighting. This will be considered later.

The second, and in some respects the more important, relates to those less stirring, but absolutely essential operations which take place outside and even sometimes inside the fighting zone, by which the necessary supplies of ammunition, food for man and beast, camp equipment, ovens, and many necessary stores that need not be particularised, as also engineering implements and explosives, pontoons, horse-shoeing forges, duplicate parts, repairing tools, ambulances and many other indispensable appliances and munitions can be carried along with the army, so that it may be kept efficient and maintained in strength and health and equipment for the exertions it must undertake.

As regards the feeding question, there is no truer saying than that which is often quoted,—that "an army marches upon its belly," and if this were kept in view we should not so often hear the cry "Why doesn't General ——— get on? What's the good of his sitting doing nothing; he seems to be wasting time terribly." If those who thus talk knew how the success of the last weeks of a month may depend on the labours of the first fortnight in getting ready for the march, in making certain that when a force does move it shall not have to stop half way in its work or even to retrace its steps, because stomachs cannot be filled and ammunition cannot be replaced, and men are worn out by bivouacking in bad weather without shelter, they would not talk so unjustly of the General wasting time, when he is getting his stores and his transport together in preparation for an efficient advance. It may give to the non-military mind some idea of what an army on the road is to state that the force which during the late war in South Africa crossed the Tugela to attack Spion Kop with its necessary transport was about nineteen miles long,



TRACTION ENGINES AND ARMY SUPPLY WAGGONS CROSSING THE ORANGE RIVER IN SOUTH AFRICA. BOTH ENGINES AND WAGGONS WERE BUILT BY MESSRS. JOHN FOWLER & CO., LTD., LEEDS, ENGLAND

ON THE MARCH IN SOUTH AFRICA. A FOWLER TRACTION ENGINE HAULING STORE WAGGONS AND A 4.7" GUN

and that Commandant Olivier in retiring northwards occupied no less than thirty miles of road.

This will serve to illustrate of what transcendent importance in war is the question of traction, and how necessary it is to consider what measures are to be adopted to accomplish it with the greatest efficiency and economy. And it is plain that if means can be found by which the length of the transport train conveying a certain quantity of material may be reduced, the difficulties of transport and supply would be diminished in a corresponding degree. And further, if speed could be increased, still more advantage would be gained. At present if a large force starts by one road, say, at 4 A. M., the last waggon may not move off for two or three or even four hours after that time, and will arrive at the end of the day's march correspondingly late. Therefore, every reduction in the length of the column and increase in the speed of movement would be a great gain.

Again, if the haulage be done by animals, delays for feeding are a necessity, and difficulties of watering may be serious and even in some cases make the use of a particular road impossible, or affect injuriously the laying-off of marches, as halts cannot be made where water is not within reach. Add to all this, that in the case of animal traction, if the weather is very wet or very dry, the road will, under the shoe-pressure of such a multitude of traction animals, dependent upon foothold for their efficiency, have its surface completely destroyed, and thus be made to cause greater wear and tear to animals and vehicles following, and possibly, if the road becomes badly rutted, to cause a serious breakdown of rolling stock, and impose much wearing fatigue on troops requiring to march by the road after some of the wheel traffic has passed.

In short, war brings into exaggerated relief every disadvantage which appertains to animal traction. It is very expensive, very slow, very cumbrous, very space-occupying, very troublesome to keep efficient, and very destructive to roads. It is also very intermittent, as both fine hot weather and cold wet weather produce exhaustion of animal power, while at the same time making traction more heavy by its own action in destroying the road surface. Thus continued movement is often impossible, and long rests for recuperation of animal power are imperative.

Notwithstanding its many disadvantages, animal traction has been till very lately the only mode of haulage in use

by armies in the field whenever any freedom of movement, either strategic or tactical, was sought for. A railway, of course, will bring forward supplies very rapidly, and as long as an army can accomplish what it has to do while clinging to a railway, no transport could be more efficient. But if an army is tied to rails, and has to limit its operation by the necessity of keeping in close touch with an iron road, its commander loses all freedom of manœuvring, and his opponent is able to forecast his every move and foresee how far he can carry it. The war in South Africa illustrated this very forcibly. As long as the commanders in the west and east of the seat of war were compelled to hold on to railways as their means of conveying bulk supplies, the Boers could take up almost impregnable positions to bar their progress. But where, with road transport, the British troops were able to move out from the railways and round the entrenched positions without losing the power to bring food and supply munitions of war to their forces, the whole scene changed as by magic, and the Boers had to abandon their carefully prepared positions in haste, and even to suffer disaster.

The use of the road being thus an essential of successful military operations, does this not open out a promising prospect for those who are engaged in developing power traction? To this there can be but one answer from all who are familiar with the progress in mechanical haulage which has been already made. Even the now old-fashioned traction engine is not a power to be despised for army transport.

At the risk of the imputation of egotism, I will say here that the Volunteer Brigade under my command was, as I believe, the first military unit to employ power traction in Great Britain for this purpose. About seven years ago, having arranged that the brigade was to march to camp as an exercise, the distance being a full day's march according to the military standard, I authorised the supply and transport department of the brigade to make a con-

A GERMAN MILITARY AUTOMOBILE DRIVEN BY AN ALCOHOL MOTOR. MADE BY THE MOTORFAHRZEUG UND MOTORENFABRIK, BERLIN

tract for the whole equipment and stores for 1500 men to be conveyed by two traction engines.

The military authorities at headquarters shook their heads over the proposal, prophesying that we should find our tents in the ditch when they should have been pitched, and our men waiting in vain for their evening meal when it should have been ready. But it was not so; our train came in in good time. There was, indeed, an accident to machinery, by which, for the last mile or two, one of our engines was not efficient; but the other, with its reserve of power, took on all the waggons and triumphantly brought them in. On our return march the whole was accomplished without a hitch. Subsequently the War Office became alive to the value of this mode of haulage, and a number of traction engines were doing excellent work in Natal. I am informed also that an efficient traction engine transport was organised in India many years ago by Lieutenant-Colonel Crompton.

But such engines, drawing trains of waggons, are not the most suitable for military transport work. A traction engine is an instrument for dragging a train of heavy waggons, a not very good mode for conveying supplies, and if one traction engine breaks down or is struck by a shell, the casualty may entail the failure to bring forward a very large weight of supplies, or even their capture. It is rather in the single, self-driven waggon of moderate size, dragging one other waggon behind it, and having a capacity for speed considerably more than,—say, double,—that of the ordinary traction engine, and with its machinery so placed as to add little to the length of the vehicle, that the most practical application of power traction for war supply is to be expected, for this would reduce the space occupied by a supply train on the road very considerably.

In the first place, as the exigencies of military waggon transport make teams of four horses in many cases a necessity, a power train of double waggons would not take up so much as half the length of road occupied by an animal-drawn train, even if the waggons carried no greater load than at present. This, both from a convenient-supply point of view and also from a military point of view, would be a much-to-be-desired improvement. For, of course, if a train is reduced to half its length, the necessary guard will employ only half the number of fighting men, and the exposure to risk of raids on the line of communications is diminished proportionately to the shortening of the line of vehicles. But the diminution would be more than one-half, for as a train of 1000 waggons will require probably 2500 horses at least, in many cases the team occupies more road than the waggon. And where so many horses are employed, a considerable proportion of the train must be taken up with the necessary supplies for feeding and the appliances for tending, nursing, shoeing, clothing, and picketing the animals, and repairing and renewing harness. Also, as one man can take care of only two horses, the equipment and supplies for many additional men must be conveyed, as compared with a system in which one man would take charge of each traction unit.

Against all this there would be nothing to set except the weight of fuel and provision for repairs on machinery. Further still, a horse-drawn military waggon can seldom be loaded up to the extent of more than two tons, even if drawn by four horses, and, therefore, there would be a still greater reduction in the length of train if each power vehicle could carry, say, four tons of load. Thus, if the horses were eliminated and the number of waggons reduced, a convoy might be brought down to one-third of the present length, or even less.

Road difficulties would also be diminished in a marked degree. The surface of the road would not be cut up as it is at present, making it, in dry weather, a sea of dust, destroying foothold and causing wheels to run heavy, and rising in clouds to parch the throats, clog the nostrils, and close the pores of man and beast, while in wet weather it becomes a quagmire, hiding ruts and hollows

produced by the excessive traffic, rendering marching a distressing exercise and traction an excessive strain on animal endurance.

The power train, one-third of the length of the animal train, could also be moved at six or even eight miles an hour, a speed twice as great as is now possible. Thus, while at present it may take several hours before the last waggon of a train can move off after the first starts, and accordingly must come in the same number of hours late at the end of the march, an efficient power system would reduce the time to one-fifth of what it is at present. The capacity of the road for movement of troops and stores would, therefore, be greatly increased, and the fatigues and risks of the road sensibly diminished, as well as the delay at the close of the march in bringing up camp equipment and providing refreshment for the weary troops. Indeed, in any cases where an advance guard reported that the country in front was clear of the enemy, the supply officers could make use of their superior speed, could take with them a fatigue party and the cooks belonging to their column, and make progress in providing a meal while the troops were still on the march. No one who has not experienced it, can realise the difference it makes to the soldier if after a long day he can at once, or at least without a tantalising delay, obtain his cooked meal. A wait of two or three hours in an exhausted condition in the evening may lower his capabilities for marching or work the next day, and his entire *morale* for more than one day, and in a very considerable degree.

No doubt British soldiers can do wonders on empty stomachs, but it is neither humanity to subject them to this cruel strain nor good sense to risk the probable evil effects to follow such hardships if it is possible to avoid doing so. Neither is it good economy, for even if the main body did not become unfit for duty, a considerable percentage must fail; and every soldier who becomes non-efficient by unnecessary failure of food, over-fatigue, or exposure is not only a unit removed from the strength, but is an expensive burden, swelling unnecessarily the labour and cost of maintaining ambulance and hospital. It is safe to predict that efficient power traction would do much to prevent risk of the soldier being exposed to such trials of endurance and the consequent loss in strength and addition to cost.

Add to all this that the mechanically driven vehicle does not require periodical stoppages of considerable duration in order to gather physical strength that has been exhausted. An animal can do only a certain amount of work in a day. The power vehicle is not limited to what is called a day's work, compelled to rest when extra work has to be done. It is as fit for work the day following a forced march of, say, forty or fifty miles, as when it has been standing idle for a day. The commander has no questions of exhausted transport animals to consider, a matter which may often be most serious, hindering his freedom for advance and greatly increasing his difficulties in retreat. All these considerations tend to one conclusion,—that successful enterprise in the construction of transport vehicles for war purposes will be of incalculable service to an army in the field.

Turning now for a short time to the combatant side of the question, it will be seen at once that the possibilities of substituting power traction for animal haulage are much more limited than in the case of transport. As regards all cases where the road is to be left for the open country, the only traction which requires to be seriously considered is that of guns, and it is evident that as these must often be forced over broken and even obstructed ground, power traction, as far as it has been developed up to the present time, is not practicable. Anyone who has seen the way in which even field batteries are made to fly over ditches, low fences, and boulder-strewn ground, and up heavy gradients can have no doubt on this matter.

Until lately there has been no development of traction at all within the fighting zone for any other purpose than the handling of artillery, ammunition supply carts, and water carts. But

A FOWLER SPRING-MOUNTED ARMOURED ROAD LOCOMOTIVE WITH A TRAIN OF ARMOUR-PLATED WAGGONS AND 6-INCH HOWITZER IN THE LATE SOUTH AFRICAN CAMPAIGN

we have in the armoured train the first beginnings of the use of power traction for combatant purposes. Both in Egypt and in South Africa such trains have done useful service, although their capacity for good work is necessarily limited by their being confined to a fixed line by railroad, which is easily destroyed, and, if in any degree broken up, may reduce an armoured train to nonentity, and expose it to capture. Of this there were several instances in the South African war, illustrating what an expensive disaster can be cheaply caused to such a fighting contrivance. But plainly it would be different if power traction could be effectively applied for combatant purposes on highways, and particularly in a country well intersected with fairly good roads.

High-speed motor vehicles, with bullet proof sides, would be of great value in the advance-guard and rear-guard work of an army. Such vehicles, capable of a speed of fifteen or twenty miles an hour, could be moved out in front for long distances, each carrying ten or a dozen men and followed by cyclists who could search the country between their own road and the next on their flank, sure of assistance from a pivot machine gun on the waggon in covering their retreat if driven in, and confident that they could run the gauntlet and get back under its protection if they were outflanked or outnumbered, the cyclists using the armoured car as cover by riding in front or at the side of it during retirement, according to the direction of the enemy's fire.

But still further, there may be good ground for believing that the introduction of power traction may prove the solution of the difficulty which to some extent hampers the efficiency of the fighting cyclist. No one can doubt that for national defence in a country intersected with fairly good roads the cyclist can be of the greatest use from his high mobility. But in one particular he is at a disadvantage. When he leaves his cycle to go where he is required in the field, he knows that there it must remain, and, therefore, that he must find his way back to that spot to recover it. Thus he has no freedom to move, being tied to his bicycle, as a child to its mother's apron string. The cycle controls him and limits his mobility.

In the case of mounted men, one man can manage three or four horses, and move them as the men move or as the manœuvring of those fighting may require. But this cannot be done in the case of cycles, and it is a most serious drawback. It may hamper an advance,

and force an otherwise unnecessary retreat and expose the cycles to capture. Accordingly, efforts have been made to construct folding bicycles which can be carried. But it is evident that freedom for fire and ability to move must be affected by the attempt to carry a bicycle over rough ground, and that it must seriously impair mobility if it is necessary to make a rapid advance, or to climb a hill, or to withdraw quickly from an untenable position. Bicycles for war must be strong, and, therefore, of considerable weight, and to carry them when off the road is hardly a practical expedient. But if cyclists were accompanied by a fast-moving armoured power-vehicle they would have much greater freedom. Ingenuity would provide a locking-bar arrangement by which the cycles could be made up in groups, so as to run upright freely when hauled by the waggon. Thus they could be taken forward or back as required. The rifleman having been brought rapidly forward by his bicycle, would be able to do his field duty without troubling himself about the safety of his machine, which would be moved about and defended by those working the small moving fort with its Maxim gun, and both could thus do their duty for the general end in view, the rejoining of cycle and man being for the time a secondary question.

Such small mobile forts as have been spoken of would certainly be useful in many ways. They might be invaluable in protecting a flank of an advance in battle, and nothing could be better in retiring for enabling a rear-guard to hold on for some time, and so check a pursuing enemy. Their high speed would also make it possible to move them by cross roads to any point of a line of battle where they might be of service, and wherever there was fairly even-surfaced grass land they could be taken off the road and run over the open country.

Like the old *testudo* of the Romans, —which was only a placing of shields together,—they would, in moving, carry their own cover against the missiles of the enemy, but with the advantage of travelling at a speed in proportion to the increased range of modern armament, and being able to disperse for fighting, with their *testudo* to aid them and on which they could fall back. They would combine some of the mobility of the hare with the hardness of shell of the tortoise. Where it was necessary to defend, or to assault a bridge or a defile, or to repel an assault, such vehicles would be invaluable to race forward and cover an attack, or to hold on as a tortoise fort in defence until reinforcements could arrive. In a day when cover from musketry fire must be sought by both attacker and defender in the field, such movable armour would often be most useful as an aid to success in fighting. There would be great gain, too, in possessing a haulage power which has no nerves and no vice, which has no tendency to stampede, never sulks, does not develop pink-eye, is unaffected by tetse fly, and never takes the bit between its teeth.

Allow me now to sketch what might be the traction equipment of an army in the field in the next great war. Out in the front, on every road, there would be armoured high-speed vehicles, equipped with pivot machine guns, to co-operate with the mounted troops and cyclists in covering the advance, feeling for the enemy, capturing and holding bridges and fords and places of vantage, and at another time aiding in the converse duties in covering a retreat, and also in general engagements giving support at points as required, and protecting flanks. In the transport there would be power vehicles with a maximum speed of, say, eight to ten miles an hour, every tenth or twelfth being a service vehicle, armoured, and of extra speed and horse-power, carrying a pivot machine gun, the driving engine so fitted that its power can be used for working purposes, each being supplied with, say, twenty or thirty fathoms of steel rope.

These service vehicles would also carry certain appliances; for example, one would have a small forge and smith's tools; another, wheelwright's plant; another, spare parts for the driving machinery; another, screw jacks;

another, pulleys and block and tackle for heavy warping work; another, small-arms repairing plant; another, spare bullet resisting plates; another, search-light appliances; another, an entrenching plough, to be hauled by steel cable; and all would carry some entrenching tools. It is impossible to detail all that might and should be provided in these armoured service vehicles. Much will have to be thought out and learned by experience before thorough efficiency will be reached. In the meantime, general suggestions only are possible. These vehicles would be the centres of defence of the convoy, and a power traction transport would have many advantages for its own defence.

In the case of horse traction, drivers must stay by their horses and manage them, but with power traction all drivers can concentrate as combatants with the escort at the armoured vehicles, thus making the defence stronger. These vehicles being mobile, could be moved as the exigencies of the resistance to attack might make necessary, and being armoured, they could offer a much more effective defence. Again, where steep hills were encountered, these service waggons, having extra horse-power, could assist the ordinary waggons. In case of necessity they could be used with their steel ropes to work the waggons up gradients, either by warping over an anchored pulley at the top of the hill, or by simply first ascending the hill and towing till the towed waggon reached the top and then returning to tow the next.

One can imagine how much time would be saved in such a case. I have seen two teams of four horses put in front of the team in a waggon to haul it up a hill, and this shifting of teams repeated time after time, the delay being very great, and the horses much overstrained. With power traction the adjustment would be simple and the fatigue nil. One can also see that where it is necessary to move heavy guns up very steep slopes such service power waggons could be anchored and used to haul by wire ropes over anchored pulleys, and with block and tackle where necessary, instead of using teams of eighteen or twenty animals, and in some cases hundreds of men. These are but some of the prospective advantages of mechanical traction. Many others will present themselves as experience widens. Lastly, these service waggons, having extra power and carrying only a light load, could be attached to and haul any transport waggons whose traction power might be disabled from any cause.

It only remains in this outline of the subject, which is intended to be usefully suggestive, to consider what is the best class of motor to be employed. It would appear that there are at present only three possible sources of power which would be suitable for the class of work which is likely to be required in war,—steam, heavy oil, or light oil. The other sources of power sometimes used in traction,—compressed air and electricity,—are evidently out of the question. Kerosene, petrol or benzoline, although they have proved themselves highly efficient for ordinary road traction, present serious difficulties when it is proposed to apply them to war transport. They are ill adapted for use in hot climates, and might be a source of considerable danger if carried in bulk in a military waggon, which may be struck by heavy shells and the volatile spirit scattered over the waggons near and set on fire. Heavy oil does not present the same difficulties, and it may be found that the progress of invention will develop this mode of traction to a high practical efficiency for waggon haulage.

Steam, raised by oil fuel or by a combination of solid fuel and oil fuel, presents only two difficulties; one is its dependence upon a water supply, sufficient in quantity and of a quality not tending to serious incrustation. Such a supply may not always be available, and without it steam traction must break down. The other difficulty is that any escape of steam would betray the presence of the convoy to the enemy at very great distances. Everyone knows how easily condensed steam can be seen over many miles of country. Upon the whole, although one must express any opinion with diffidence, it seems likely that ex-

plosion engines worked with heavy oil give the greatest promise of success for war transport.

While on the Continent and in America attention in motor traction circles seems to be mainly concentrated on fast passenger vehicles, much progress is being made in Great Britain in the development of heavy van and waggon power traffic. Those who are engaged in the study of this important branch of a new industry may rest assured that there is a great field open for design of vehicles suited for war purposes. The South African war has led to the announcement of many changes in the military organisation of British forces in time of peace. One of the most important of these is that the Volunteer Force is to be supplied with transport, the purpose being that there may always be a large number of standard military vehicles ready for use in an emergency. It will lie with the manufacturers of mechanically driven waggons to convince the War Office authorities that they can turn out efficient vehicles for transport purposes. If so, it is difficult to believe that they will not be adopted and orders given for their supply to the home defence forces.

In time of peace, transport carriages must necessarily stand idle for considerable portions of the year, particularly if employed for Volunteer Corps. Intermittent horsing is always expensive, and, as a preparation for active service, most unsatisfactory. But the motor part of a power waggon can be always ready for use, and will cost nothing for up-keep beyond the price of proper preservative grease when it is laid up unused for a time. At any moment it can be turned out efficient, and the training for its management under proper skilled inspection is not difficult And as the waggons can be constructed for heavy loads, and can cover at least twice the number of miles that can be covered by animal traction in any given time, a much smaller number would be necessary, thus compensating for any extra initial cost per waggon.

John Bull is a slowly moving and cautious person. He does not readily take up anything that is new-fangled, and perhaps in no department is he more inclined to be ultra-conservative than in affairs military, and in upholding the horse as against the machine. But the late war will, it may be hoped, rouse him up, and induce him to look for himself for the best war equipments he can find, instead of waiting till they are forced upon him by the certainty that he is lagging behind the rest of the world. Certainly, his love of the horse ought to cause him to save the noble beast from the cruel trials that the necessity of the case imposes upon it in war. As Mr. Bennet Burleigh, in one of his graphic letters from the seat of war, says,—" I fear the amiable Society for Protection from Cruelty to Animals would despair of us and itself were its representatives here; they would have so much that is impossible to attempt to put right. It is suggestive of a more than healthy appetite to see horses wildly browsing upon African heather and scrub, or plunging for the straw casings of old bottles and hamper stuffing. Hardship is an accompaniment of campaigning, but there are occasions when it passes into downright suffering."

Other nations, and notably Germany, are working at the problem, and we are told that the German Emperor has offered a large premium for the most suitable motor-vehicle for war purposes. British designers must not be behind the world, nor must they wait for offers of premiums. They must put trust in their own exertions and in nothing else. Let them put before the country specimens of their thought, their experience, and their inventive power,—vehicles which will not break down under trial, but will be as efficient for the road as the locomotive engine has so long been for the rail.

If this important matter is taken up promptly, there is good ground for the belief that those who do so will have the honour and the gratification of doing notable service to their country. The hackneyed saying, " Business before Pleasure," is expressive of a great truth. But it is no rash prophecy to say that those who provide us with

efficient motor power for war will have both the satisfaction of doing good business and the patriotic pleasure of accomplishing great work for the State.

[It may not be uninteresting in connection with the subject here to refer also to an address made not long ago by Colonel R. E. B. Crompton on the use of traction engines in the South African campaign. Colonel Crompton told that when Lord Roberts wanted to put heavy guns into a position which was difficult, he always sent for traction engines. The engines did twice whatever the Boers did, and twice whatever the British sailors did, although the latter had by pluck and muscle got guns weighing five or six tons into difficult positions. The lesson of the war as regarded automobilism was striking. The whole of the Transvaal was one mass of dead animals; it was impossible to feed them, and they died of starvation. The great outbreak of enteric fever was caused by the mass of dead and dying animals, but there was not a dead traction engine in the whole of South Africa.

To show the importance of automobilism he said that when he was managing a line of steam traction from Pretoria to Rustenburg they carried about 130 tons of food per week for two columns twenty or thirty miles west of Pretoria. Thirty tons of that amount were food for men and 100 tons food for horses and mules. If they could have supplied self-propelled vehicles to the columns they could have cut down the weight to 7 or 8 tons of fuel in place of the 100 tons of forage. It would be found, he declared, if it had not been already proved, that all the heavier things, such as guns, waggons, engineers' park, etc., could be transported most successfully by self-propelled machines, either steam or oil. It was important that something should be done to relieve the cavalryman and mounted infantryman of the huge weight the horses had to carry. He wanted to see the service supplied with some light vehicle that could accompany the cavalry and mounted infantry and carry part of the weight which killed the horses and destroyed the mobility of the British army. As an instance of what traction engines had done in South Africa, Colonel Crompton stated that he had seen engines take a 10-ton gun up a gradient of one in five at the rate of a gallop.—THE EDITOR.]

MUNICIPAL SOCIALISM IN GREAT BRITAIN

By James Boyle

The brief review of some of the features of municipal socialism in Great Britain, given in the following pages, was prepared by Mr. Boyle in his official capacity as United States Consul at Liverpool and was transmitted to his goverment as one of the regular United States Consular Reports. In connection with its publication here, it may be worth while to refer to an earlier article, entitled "Municipal Trading in America," contributed to this magazine for April, 1902, by the Hon. Robert P. Porter.—THE EDITOR.

FOR some years past there has been a quiet but gradually increasing development of a certain phase of socialism in Great Britain. Reference is made to what is generally known as "municipal trading," and sometimes, and more correctly, as "municipal socialism." The first appellation is rather a misnomer at the existing stage of the movement. Municipal socialism does not mean a division of private wealth or property "share and share alike," but the ownership and operation of certain undertakings and enterprises by the municipality for the public good, as claimed.

As generally explained, the enterprises within the proper sphere of municipal socialism are "public necessities." But here arises the question, Where is the line to be drawn? This line is, by the great majority of advocates of the system, drawn at those enterprises and undertakings which by their very nature are essentially public or semi-public in their functions, and which are of necessity more or less monopolies,—as, for instance, street railways, waterworks, gas lighting, electric lighting, and electric power supply. Incidentally, it may be mentioned that the domain of "national socialism" has been entered into by the British Government by its ownership of the telegraph system and by its proposed gradual absorption of the telephone system; and a movement has sprung up for the nationalisation of the railways, and even of the coal supply, as well as of storage of wheat for use in case of war. In 1875 the capital invested in municipal undertakings in Great Britain was £93,000,000, while in 1900 there were invested £300,000,000.

There are now in Great Britain 931 municipalities owning water-works; 99 owning the tramways; 240 owning the gas works; and 181 supplying electricity. Most of these are in England. Municipalities were not allowed to work the tramways until 1896. It is estimated that half of the gas users in England use municipal gas. In a number of places,—Liverpool among them,—the municipalities supply electricity for lighting and power, while the gas supply is still in the hands of private corporations. In the case of Liverpool, the gas company is quite willing to sell to the municipality, but the latter will not buy; first, because under the charter of the gas company the municipality would be compelled to pay a perpetual dividend of 10 per cent. to the stockholders, and, secondly, because it is believed that in the near future electricity will practically supersede gas as an illuminant.

The municipalities of Leamington and Harrogate own Turkish baths, two of the best at present existing in Great Britain, and Harrogate also gives fireworks displays at municipal cost. Glasgow, like Liverpool, owns its waterworks and trams, and provides municipal lectures. Glasgow has quite recently reduced the fares on the tram-

cars, so that there are now not only half-penny fares, but a distance of two and one-half miles can be travelled for one penny. Universal penny fares will probably shortly be introduced in Liverpool. The "transfer" system, as prevailing in America, is not used in Liverpool, nor in any other British municipality, so far as I know. Glasgow was the first city to establish a "municipal palace." Manchester owns shares in its ship canal. Out of its municipal tramway profits Sheffield has appropriated £15,000 for the erection of shops and business premises, which it will rent. Quite recently the northern townships outside of London bought the well-known Alexandra Palace, where the municipal authorities maintain an auditorium and give organ recitals and theatrical, military band, and variety entertainments of all sorts, and industrial exhibitions. Torquay owns a rabbit warren; Colchester possesses an oyster fishery; St. Helen's, a chemical centre, supplies sterilised milk; Hull owns a crematorium; Doncaster and Chester own race courses (the former actually managing the races); Bournemouth owns one of the finest golf courses in Great Britain; West Ham, a borough of London, owns a stone-flag factory; and Bradford owns a hotel,—as also does Liverpool (on its water-works property in Wales).

Bristol has municipalised its docks and harbour, at a cost of between £2,000,000 and £3,000,000. The docks of Liverpool are municipalised in a modified way. The system is peculiar to Liverpool. This vast estate is administered by a public trust, nearly all the members of which are elected by those who pay dock dues, and the profits, after deducting expenses and payment of interest on capital account, go to improvement, and not to the benefit of a private corporation. The probability is that the London docks will before many years be managed under either the Bristol or the Liverpool plan. Nottingham, in addition to owning parks, markets, artisan dwellings, baths, and a hospital, has bought a castle and a forest, and has a natural history museum and a school of art, and was the first municipality in Great Britain to have a university college. The last item gives occasion for the statement that several English cities have within the last year or so taken up the question of local universities. Birmingham has established one, and Liverpool will shortly follow suit.

Liverpool is one of the foremost cities in municipal socialism. It owns the water-works, one of the best systems in the world; it operates the tramcars; it supplies the electric light and power; it has one of the largest and best public-bath systems anywhere, and proposes to erect the finest Turkish bath in Europe; it provides public laundries for the poor districts; it furnishes flowers and plants for the windows in the slums; it sells sterilised, humanised milk for the children of the poor at cost price; it has a salaried organist to play its famous municipal organ; it gives municipal lectures,—and all these in addition to the usual undertakings of municipalities, such as parks with concerts, technical schools, etc. But the greatest socialistic undertaking by the Liverpool municipality is that of providing dwellings for the very poor, the dispossessed tenants of demolished insanitary dwellings of the slums.

The one great predominating question in connection with municipal socialism is the "housing question,"—that is, the demolition of "slums" and insanitary dwellings and the erection, by the municipality, of suitable dwellings to take their places. The terrible conditions existing in many of the large cities of Great Britain as to the housing of the very poor is a heritage of former social and economic conditions, as well as of feudal land laws, and of the past indifference both of the municipalities and of Parliament, as well as of the public generally,—even, it may be said, of philanthropists. But heroic efforts are now being made in many of the large cities, and Liverpool is in the front rank, in the efforts to remedy this deplorable condition of affairs. Many difficulties have been confronted and overcome which at first were thought to be insurmountable,

—and these in addition to the perplexing moral and social questions involved. One great difficulty is that of compensation to the owners of insanitary property. In England the doctrine of "vested rights" is generally held very tenaciously. London has spent nearly £3,000,000 in clearing away insanitary property. In some districts of London it has cost from £300 to £500 for every family turned out. These large sums refer only to the clearances of the slums and to the compensation of the landlords, and do not include the amounts spent on the construction of new municipal houses. An agitation is being raised against the past generous compensation of owners of insanitary property, and it is claimed that under the present Act of Parliament these owners can be prosecuted for allowing their property to become insanitary.

Another great difficulty has been the question of providing an adequate number of suitable municipal dwellings ready for occupancy at the same time that the unfortunate dwellers of the slum houses are dispossessed of their tenancy. Inattention to this necessity has called forth indignant protests in the large cities of Great Britain where the municipal scheme has been adopted as a solution of the slum problem. Glasgow, for instance, is said to have had at one time 50,000 people turned out of their homes by the corporation (of course, not all together), while it provided housing accommodation for only 7000. In the initial stages of the municipal housing scheme in Liverpool the same difficulty presented itself, but the "housing committee" of the corporation have recently pledged themselves that they will not undertake any scheme of demolition until they have provided adequate accommodation elsewhere for the dispossessed tenants.

Under the present Act municipalities are compelled to provide substitute accommodation for at least 50 per cent. of the dispossessed occupiers of slum property. The Act under which municipalities demolish insanitary areas and erect dwelling houses seems to be of a most comprehensive character. It not only authorises a municipality to construct a house, but it "may include a garden of not more than half an acre, provided that the estimated annual value of such garden shall not exceed £3." And the municipality, if it builds a cottage, can "fit up, furnish, and supply the same with all requisite furniture, fittings, and conveniences."

There are two principal slum areas in Liverpool,—one in the north end of about 383 acres and another at the south end of the city of about 100 acres. Most of the houses in these two districts are structurally insanitary. There are rows of them, built "back to back." There are other districts where houses have been made insanitary by overcrowding and by the habits of the people. The original number of structurally insanitary houses, when the corporation commenced operations, is estimated to have been about 22,000. Of this number the corporation has demolished about 8000, and private owners and builders have demolished about 4000 more. There are thus still about 10,000 insanitary houses to be dealt with.

The average number of persons in these insanitary houses is five per house. Slum houses in Liverpool are generally of three rooms, one above another, although, as a rule, the third or upper room (really a garret) is seldom used. Under an Act applicable to Liverpool, passed in 1864, compensation is paid to owners of insanitary property which is demolished, such property having been condemned on a presentment of the grand jury upon a report of the medical officer of health. The corporation is also using the powers conferred upon it by a general Act passed in 1890 providing for the "housing of the working classes" This Act provides for compensation, as a rule; but still, under a certain provision of the Act, there can be a "closing order" against any house which is in a state so dangerous or injurious to health as to render it unfit for human habitation. If, on receipt of a closing order, the owner makes the house fit for human habitation, nothing more is done; but should there be any default on his part, an order for demoli-

tion may issue without any claim for compensation, in case the premises are a danger to the health of the neighbourhood. Under both the local Act of 1864 and the general Act of 1890, where the owner does not elect to retain the site, the corporation must of necessity acquire both land and buildings. In some cases the land thus acquired is sold by the corporation to private individuals on which to build houses, subject to certain restrictions, so as to secure improved sanitary conditions. In other cases the corporation itself has built blocks of dwellings. Already nearly 900 tenements (or suites of rooms) have been erected, and 1301 additional tenements (or suites of rooms) are in course of building or contemplated.

The Liverpool municipal dwellings are mostly in the form of blocks of tenement-houses, three or four stories high. The local government board (a bureau directly under the control of Parliament) insists upon certain provisions to meet the necessity of dispossessed tenants before sanctioning demolition operations. Until 1899 there had been a conspicuous failure to meet this obligation, but since then the wants of dispossessed persons have been carefully foreseen and met. The present policy is to have blocks of dwellings ready within convenient distance, into which dispossessed tenants can go immediately they remove from the condemned property. Most of these tenants are dock labourers or of a like class. It is claimed that Liverpool alone among the municipalities of England and Scotland has been successful in supplying a type of building within the financial means of the poorest of the poor. A single room can be had for as low as a shilling a week. The rent of two rooms ranges from 2 sh. 5d. to 3 sh. 2½d; that of three rooms, from 4 sh. to 4 sh. 5d.; that of four rooms (the largest suites provided), from 5 sh. to 6 sh. The fixtures are simple, but superior to those supplied in like dwellings by private landlords.

In a few dwellings hot water is supplied. Others have gas, paid for on the "slot" principle. A pennyworth is sufficient for four or five hours' consumption by one burner. Since Liverpool went into this enterprise it has paid £385,000 for demolished property, and, in addition, several pieces of land have been purchased, costing £67,165, for the erection of municipal dwellings. The cost up to date for construction alone has been £146,571. The total burden on the local taxation as the result of these combined operations amounts to 1¾d. in the pound sterling. The rents paid are insufficient by about 2 per cent. to meet the cost of the dwellings, without counting anything for a sinking fund, depreciation, etc. The present effort of Liverpool is to provide housing for the dispossessed tenants of condemned slums. It will probably take twelve years to complete this task. Then, the question of providing better accommodations for artisans and mechanics will possibly be faced. Liverpool, it is said, owns more revenue-producing real estate than any other municipality in the world, its income from this source being about £100,000 a year.

The London County Council has within a recent period taken hold of this housing question with a firm and comprehensive grip. There will not be as much compensation paid to owners of slum property as formerly. One scheme adopted by the London County Council provides cottages for 8000 people; another (and this is on an estate outside of the London boundary line) will accommodate 6000 people; and a site has been bought where 42,000 are to be accommodated in pretty little cottages, with gardens. London undertakes to provide for the artisan class, as well as for the "casual," and in that particular it is in advance of Liverpool.

Strange to say, the housing question is getting to be an acute one in the country districts, as well as in the British municipalities. It is claimed that one of the reasons why the rural population flock to the cities is because many of the great landowners not only fail to erect decent residences for the labouring people, but some of them actually refuse to allow cottages to be erected on their estates, either because of æsthetic rea-

sons or because the labourers' cottages would have a tendency to depreciate the value of the estates to prospective wealthy purchasers.

Liverpool boasts of having one of the best tramway systems not only in Great Britain, but in Europe. The corporation got control of the system in September, 1897, and has substituted electric for horse trams. At the date named there were 68 miles of tracks within the city and about 7 miles in the surrounding district connecting therewith. There were then 287 cars, 156 omnibuses, and 3623 horses. The municipality paid £567,375, the purchase price covering tramcars, omnibuses, good-will, vested rights, etc. In November, 1898, an experimental electric line 5 miles in length was opened. The work of reconstructing the new lines commenced in January, 1899, and by the end of 1900 100 miles of lines were completed, including extensions. The overhead trolley system is used. Of the entire 102 miles of the track laid down, 6 miles were laid with American rails, and 5 miles with German rails; the remaining 91 miles were laid with rails of British manufacture. The first fifteen motors and fifteen "trailer" cars for the experimental line were obtained from Germany. Subsequently, fifteen Brill cars were obtained from the United States. The balance of the cars are of British make. In reply to my inquiry as to whether there has been any discrimination in favour of British rails, cars, electrical equipment, etc., as against American, German, or other foreign make, and whether the contracts were made under competitive bids, I am officially informed by the manager that tenders were invited and the most advantageous were accepted.

Most of the cars in use and all those now being made are of what is known as the standard Preston type. This car is shorter than most American cars, and has a "reverse" staircase for top outside seats. Each car accommodates twenty-two inside and thirty-four outside. In fine weather the outside of cars and omnibuses is preferred in Great Britain to the inside. Experience has shown that the style of car used in Liverpool gives the most satisfaction to the British public. There are no "summer cars" of the American type; the weather is too variable. The fares charged are by distance. One penny is the lowest fare for which 3 miles can be travelled; 5 miles 308 yards can be travelled for two pence; 7 miles 287 yards for three pence; and 8 miles 495 yards for four pence. The total traffic receipts during 1901 were £468,383. The percentage of working expenditure to gross receipts is 63.7. Parliamentary powers are being obtained to devote not exceeding one-third of the net profits to the relief of the rates; the balance of net profit goes to a renewal or reserve fund. The total number of employees is 2293, of whom 646 are drivers, 595 conductors, 117 inspectors, etc. Drivers and conductors work ten hours per day. Under the old system, before the municipality took charge of the tramways, the average working day of conductors and drivers was fourteen and one-half hours. They are now paid six pence per hour. After twelve months' service with merit, twelve pence per week extra is paid for each period of ten years of approved service. Under the old régime, drivers received £1.8.0 per week, rising in eighteen months to £1.15.0 per week; and conductors received £1.4.5 per week, rising in three years to £1.8.0 per week. The rate of pay under the old régime was for seven days a week. The system already extends outside the city boundary, and it is proposed to connect it with lines of a new enterprise in which American capitalists are interested, known as the South Lancashire Tramways Company, and which will form a network of tramcar lines between Liverpool and important towns in South Lancashire.

Several municipalities have adopted what is known as the "direct" system of labour as contra-distinguished from that of the "contract" system. This is notably the case in London. The County Council of London employs workmen on a principle which is "based on the rates of wages and hours of labour recognised by associations of employers

and trades unions and in practice obtained in London." There is also a stipulation that "where in any trade there is no trade union, the Council shall fix the rates of wages and the hours of labour, and shall, from time to time, revise the same as may be necessary."

A great deal of opposition has sprung up against this system of direct employment, and the opposition has made much capital of the alleged fact that the bricklayers employed by the London County Council under the above conditions, lay down only one-half or even one-fifth as many bricks per day as contractors get laid even by union labour. On the other hand, the claim is made that the municipality gets its work done cheaper in the end because it does not have to pay profits to contractors and other middlemen. Speaking generally, nearly all of the work done by municipalities, even when municipal ownership prevails, is by contract; but, as a rule, these contracts are given out subject to what is known as the "fair-wage" condition, which is substantially the wage condition adopted by the London County Council. In connection with this question of direct labour, it is interesting to note that many British railway companies adopt it, they making all their engines and rolling stock themselves; and this, by the way, is given as one of the reasons why the outside British makers of locomotives are not able to meet foreign competition. They have not got patronage enough to warrant them in keeping their plants up to date.

One of the greatest examples in Great Britain of "direct" labour is furnished by the Liverpool Dock Board. This board formerly did all its work itself. The question of cost did not primarily come in, but the principal reason for direct labour was the belief that it would not be safe to trust contractors with the kind of work to be performed. For two or three years past, however, a great deal of work has been given out by contract, and it is claimed that the contract work is done just as well as that performed by direct labour, and much cheaper. One of the greatest objections urged against the employment of direct labour by municipalities and large corporations is that the tendency is to perform the work "too well,"—that is, to make it unnecessarily heavy and substantial without any discrimination being shown as to work that can be lightly done, the object being to "string out" the job. And the further objection is made that when a municipality or public trust has its work done by direct labour, the employees do not work nearly as hard as do employees of private contractors, and, as a rule, get more pay than those who work for contractors.

The advocates of municipal socialism in Great Britain have been gradually increasing their demands, and now a point has been reached where even many supporters of that system feel called upon to cry a halt. Within the last year or two an active opposition has grown up in Parliament to municipal trading. There are two schools of thought among municipal socialists. In the first school are those who not only advocate the municipalisation,—and in certain lines the nationalisation,—of such enterprises as water-works, street railways, electric lighting and power supply, and railways, but who favour the public control of all departments of human production and energy,—not suddenly, but by degrees,—and the abolition in time of the private manufacturer, trader, or tradesman. These form the extreme school of national and municipal socialists. Their number is possibly increasing, but, without a doubt, their opponents are in an overwhelming majority, even among those who favour the present stage of municipal socialism.

Speaking generally, the enterprises of municipal socialism in Great Britain have been within well-defined lines. In a recent article in a London periodical, *The Queen*, the Hon. Lionel Holland says:—

> Those, finally, who contend that municipal trading trenches upon the proper sphere of individual enterprise betray a singular want of the faculty of discrimination. There is a class of undertakings which inevitably tend to become monopolies, when the public loses the advantage of competition,—the great merit of private enterprise,—which concern the satisfaction of wants common to the community, when, by resigning their supply to private

speculators, the community is deprived of effective control over matters vital to its convenience; whose functions are of a semi public nature, and require the sanction of the law to be put into operation. Such undertakings are clearly differentiated from the ordinary operations of private traders; they can only with justice and advantage to the community be vested in a representative body, to be conducted for the profit and convenience of the public.

The above may be accepted as an accurate definition of the limitations laid upon most of the experiments in municipal socialism so far undertaken in Great Britain, although there are plenty of examples indicating the all-embracing programme of the advanced municipal socialists.

It has got to be quite the fashion in Great Britain to laud the municipality as being of far more vital concern to the people than Parliament. The claim is made that local government in Great Britain is as nearly ideal as it can be. One of the greatest advocates of municipal socialism, Mr. George Haw, in a recent work, "Municipal Government, the Hope of Democracy," says:—

Neither America nor France, under republics, excels our municipal code. We have the largest franchise and widest powers. Americans themselves admit that our municipal institutions are fifty years in advance of theirs.

A number of changes in the municipal code of this country are being suggested, but it appears that most of the apostles of municipal socialism concede that the present code is amply sufficient for the widest development of their views. Mr. Haw, in his work just quoted, says that "the fault with us is that we have not learned to make full and good use of what we have won." Speaking of the democracy of Great Britain, he adds:—

"It has now no need, as of old, to look to Parliament for reform, but to look to itself." Municipalities are held by an ever-increasing number of people in this country to be the legitimate and most practical medium for the development of the principles of socialism, and voluntary organisations for this purpose are being discarded, the existence of statute law being deemed necessary, both to do and to restrain, to insure success.

The claim is made that the best-governed towns in Great Britain and the towns that have the least taxes are those where municipal socialism prevails. But this claim is strongly controverted, especially as to ultimate results; and the opponents of municipal socialism charge against that system a tendency to extravagance, jobbery, official indifference, and lethargy, and the broader charge is made that the system contracts and paralyses individual effort and enterprise. Yet it should be kept in mind, in connection with this criticism, that municipal socialism has in some cases been embarked upon almost out of necessity,—as, for instance, in the case of the housing of the poor in Liverpool, where private enterprise has not only failed absolutely to solve the problem, but has not even alleviated its most crying evils.

Two observations are appropriate to be made in conclusion:—Speaking generally, municipal government in Great Britain is honest, intelligent, and energetic; and, as a rule, politics has but little to do with the engagement or retention of civic employees.

A PACK TRAIN 14,000 FEET ABOVE SEA LEVEL

MINING AT HIGH ALTITUDES

BEYOND THE TIMBER LINE IN COLORADO, U. S. A.

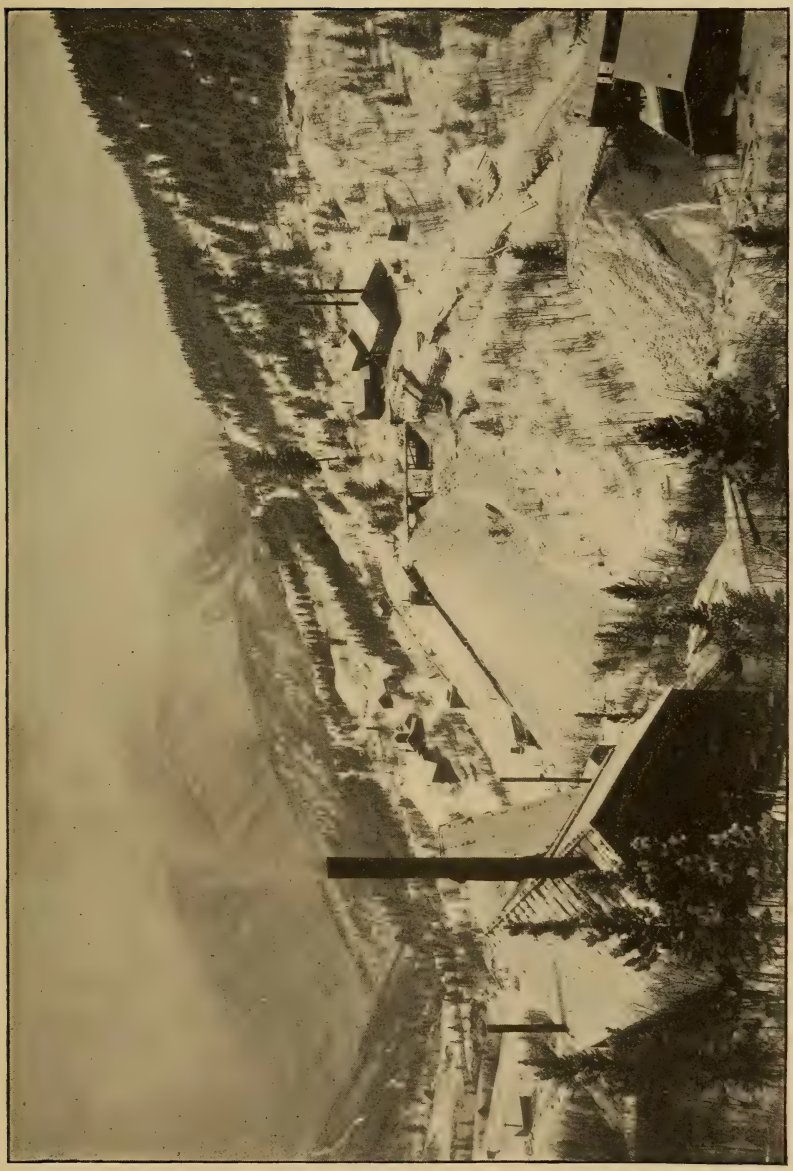
By T. A. Rickard

OF the numerous mines which produce the precious metals, at a profit, in Colorado, none are at a lower altitude than 7000 feet above sea-level. On the other hand, the loftiest mine is the "Present Help," on Mt. Lincoln, which is at 14,202 feet. It can also be stated that the bulk of the gold and silver yield of the State comes from the workings of mines situated between 9000 and 12,000 feet above sea-level.

Altitude is a relative term. I remember climbing up one of the ridges of the Southern Alps, in New Zealand, and coming upon a little mine called the "Sunrise," the owners of which assured me most gravely that it was the highest mine "in the world." This was at about 7000 feet. They looked at me askance when I said that where I lived we had no mines so low, and, doubtless, if you told those who work in the loftiest mines in Colorado that in the Andes of South America the high regions of mining begin where they leave off in the Rocky Mountains of North America, the statement would wreck a reputation for veracity.

However, absolute height above sea-level does not measure the amount of difficulty, danger, and picturesque environment which belong to mountain mining, and, therefore, it is much the same whether you go to the "Sunrise" from Lake Wakatipu, to the "Tomboy" from the plains east of Denver, in Colorado, or to the "Potosi" from the tablelands of Bolivia.

At this time we will consider mining at high altitudes as it is understood in the Rocky Mountains, more particularly in Colorado, where this range culminates in a magnificent complex of interlocking ridges, the summits of which repeatedly rise to heights of over 14,000 feet. The topmost peak of all is Sierra Blanca, with a record of 14,483 feet. This is a part of the serrated Sangre de Cristo range, and separates the Wet Mountain and Huerfano valleys from the broad San Luis plateau, the contour of the mountains merging into the level line of the plain with a sweeping curve which is a constant delight to the beholder.



WINTER AT HIGH ALTITUDES

THE YANKEE GIRL MINE

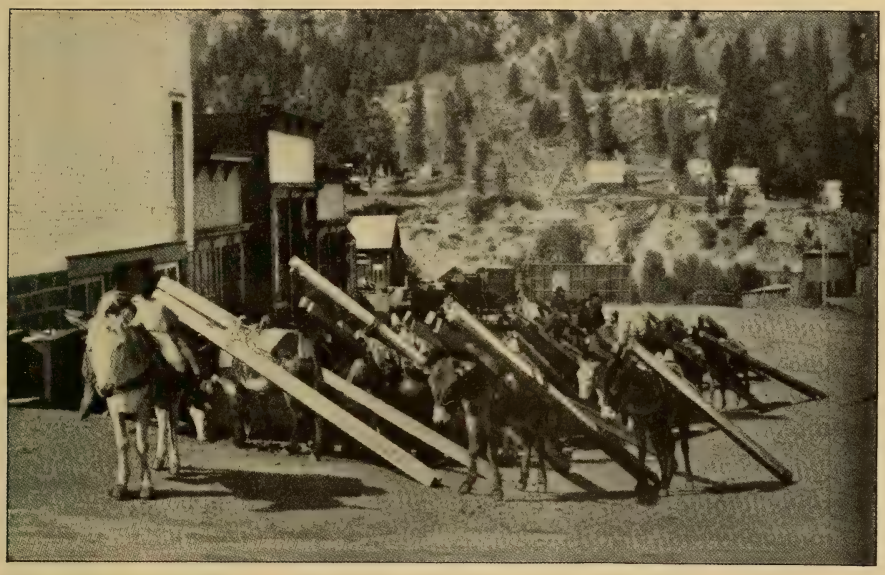
In the highlands of Colorado the mean level of tide water is not the only datum line for measurements of altitude. Many who inhabit the mountains have never heard "the innumerable laughter" of the sunlit sea, nor have they seen "the ocean's Alpine azure rise and fall." To them the distant ocean, 1500 or 2000 miles away, is but a misty, unknown magnificence. They do not employ it as a necessary point of departure, because there is one closer at hand, namely, the "timber line," that well-defined horizon which, like the shore of an ancient sea, runs a distinct level across the face of all the mountains. Below, the forest grows luxuriantly, but at about 11,000 feet the dark armies of the pine begin to scatter, and in their straggling array they look like mountaineers, who, hurrying toward the summit, stop for want of breath. This is timber line. Above it the desolation is unrelieved, frost and snow do their worst, and the bare rocks rise in dumb protest to cloudless skies.

THE CAMP BIRD WIRE ROPE TRAMWAY NEAR OURAY. ERECTED BY THE TRENTON IRON COMPANY, TRENTON, NEW JERSEY

The difficulties to be overcome in the operation of mines at these high altitudes are not without compensation, as will be shown. Chief among the drawbacks, however, are the shortness of the summer season, the scarcity of both water and timber, the high cost of carriage and danger from snowslides.

During the larger half of the year ice and snow hold dominion. When summer compels them to relax their grip, the sun strikes through the clear air with such directness as to melt the snow fields with great rapidity. There ensues an excess of water where before there was a want. This is the wet period in the underground workings of the shallow mines, because the shattering of the rock by frost, so evident above the timber line, opens up a ready passage for surface waters. After the early summer the water disappears, and a dry season supervenes until the snowstorms of autumn come and go, distributing their brief moisture. If the mines were not so near the crest of the watershed they would get some service out of the summer thaws, but they are situated too near the fountain head; the water from a thousand runnels has not yet mingled, as it does lower down, to form a steady stream of beneficence to man and beast.

The snow fields, as they melt before the fierce sun of this cloudless horizon, give a temporary energy to the noisy torrents, or sink down through the rock crevices only to appear again as the waters supplying the springs that dot the lower hillsides with brilliant patches of green. What moisture there is upon these high mountain ridges is, therefore, short-lived,—a brief phase between the dry snows of winter and the dry, windswept rocks of the late summer.



A BURRO BRIGADE. CARRYING TIMBER TO THE MINES

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To this is due the origin of the timber line, which marks the limit of tree growth, not by reason of cold or of altitude, but because the lack of moisture puts a bar to the further ascent even of the courageous pine. This becomes a factor in mining also because all the mines above 11,000 feet are compelled to send lower down for the timber which is used to secure the underground excavations. This means hauling up, instead of pulling down. It applies to lumber also, which ordinarily

AN INTERMEDIATE STATION ON THE CABLEWAY OF THE BESSIE MINE OF THE SAN JUAN GOLD MINING COMPANY AT TELLURIDE, COL. INSTALLED BY THE A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

below timber line is sawn on the ground or near by. At the "Tomboy" mine, which is near Telluride, at 12,000 feet above sea-level, the cost of lumber is $23.50 to $26.50 per thousand feet (board measure). Of this, $7.50 represent the charge for bringing it up the hill. Stulls (large mine timbers) cost from 22 to 23 cents per foot. Of this, over one-half, 12½ cents, represents the haul up the mountain. These figures bring home the economics of mining above the clouds.

In the winter the roads are blocked by snow, and even the trails along which the faithful burro can make his patient way become obliterated, so that food and other necessary supplies cannot be delivered at the mines during intervals of many weeks. This makes it necessary to lay in a stock of provisions, mine supplies, timber, and other necessaries, so as to tide over those periods when the men, who live amid the snows, are cut off from their fellows as effectually as if they were on a coral reef in mid ocean.

During recent years the telephone lines have been extended to the principal properties, and communication is in some sort maintained, in spite of the interruptions due to breaks in the line consequent on windstorms. However, even now there is a certain amount of isolation which gives a distinct character to life amid the upper snow fields. The food is, of course, chiefly canned, particularly a sto vegetables; yet fresh meat is served at most of the big mines, and is easily kept fresh during the cold months. Nevertheless, there is an inevitable monotony of diet and a weary iteration of life from day to day which is suggestive of the mariner on a lonesome island. High wages for the men and high hopes of success on the part of the owner or his manager compensate them for their wintery exile.

The shortness of the summer affects work in another way. It prevents operations upon the immediate surface except during a restricted period; that is to say, actual prospecting or superficial excavating of any kind is stopped by the winter. The erection of machinery or of buildings must cease when the first snow comes. Therefore, mines at their inception are handicapped; the prospect which has been opened up during the summer must often be abandoned until the following summer; and the decision to install an engine or erect a tramway must be arrived at early in the year if it is to be put into effect.

Transport is a serious item in mountain mining. The roads and trails which connect the high mines with the outer world are necessarily steep and circuitous. Even under the best conditions, in summer, the loads pulled up these zigzags are small in ratio to the horse-power employed. Thus with four animals, averaging 1250 pounds apiece, a load of 6000 pounds, distributed between the waggon and its contents, can be hauled along an average mountain road at the rate of one and one-half miles per hour. Such roads have a maximum gradient of 12 per cent.

On a typical American highroad the cost of freighting by waggon averages 25 cents per ton per mile. As an example of the expense of transport over a mountain road I can quote the work

ANOTHER VIEW OF THE SAN JUAN GOLD MINING COMPANY'S ROPE TRAMWAY AT TELLURIDE

THE DESOLATION OF TIMBER LINE ABOVE TELLURIDE. THE "TOMBOY" MINE IS SEEN IN THE FOREGROUND

done by a six-horse team between Eureka and the San Juan Chief mine, —a distance of seven miles. They hauled, on an average, five tons of ore down and brought three tons of coal up. The charge was $2.50 per ton of ore and $5 per ton of coal. Thus the cost of hauling to the mine was 70 cents per ton per mile and the cost of bringing ore down was about 35 cents per ton-mile.

When the road has a gradient exceeding 12 per cent. it is more economical to pack, that is, to transport material by loading it upon the backs of mules or donkeys. The average cost of this method of transport is from 75 cents to $1 per ton per mile when there is nothing to be brought down. When there is a back load the cost is, of course, less. Thus, in packing from Eureka to the Sunnyside Extension mine, a distance of seven miles, of which one-half is comparatively easy, the rate is $5 per ton, with no back load, while it is $2.25 per ton for packing ore down from the mine and $3.50 per ton for taking coal up.

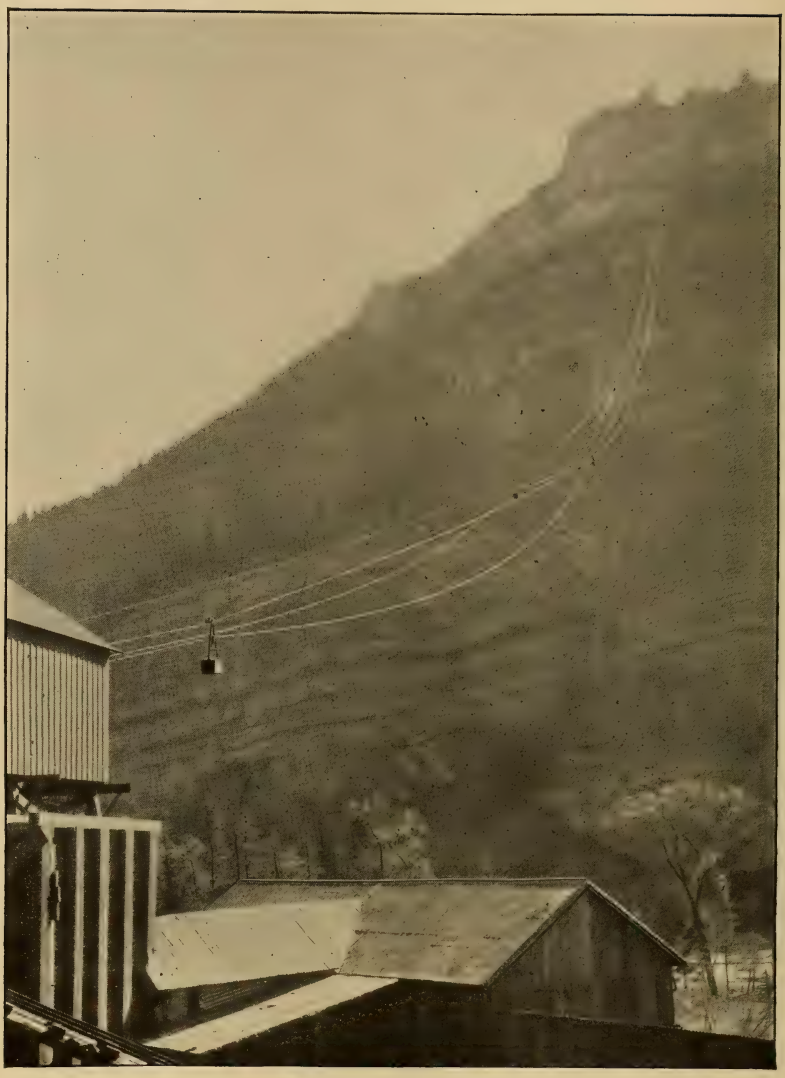
Both mules and burros (donkeys) are employed in this work. When mules are used, they are strung along in a line and connected by rope. A man rides the first mule, and thus leads the entire cavalcade. When burros are substituted, they are not tied together, but each goes loose and the owner drives them like a flock of sheep. A mule will carry 250 pounds up-grade and 350 pounds down, while a burro can manage an average of 200 pounds. Where grass grows on the mountains, the burro is preferable, because he can manage to subsist on it; but where fodder only is fed, the mule is more economical.

Reference has been made to the fact that the snow water drains off the high ground with a rapidity which prevents the utilisation of it by the mines situated above timber line. Occasionally it becomes stored in a mountain lake, but this is unusual above 11,000 feet. Silver Lake is a striking exception. One of the largest properties in Colorado, —the Silver Lake mine, —is situated on the shore of this body of water, which was, at one time, utilised for milling purposes. It was the result of the experience of the former owner of this mine, Mr. Edward Stoiber, as it has become the general experience of the region, that it is more economical to place your mill in the lower valley, near cheap fuel and a perennial water supply, than at the mine itself, especially now that the construction of aerial ropeways permits of an inexpensive transport of ore from mine to mill.

Indeed, it can be said that the most interesting feature of mountain mining in Colorado has been the development of the wire-rope tramway. The first tramways brought into use at high altitudes were those of the Huson and the Hallidie type, in which the buckets are attached to the one wire rope which supplies the tractive force. Then came the double-rope system, of the Bleichert and Otto types, in which the buckets are drawn over a large stationary cable by means of a small traction rope.

Experience now favours the latter type, in spite of the fact that its installation costs from 30 to 50 per cent. more. In the first place, the cost of maintenance of the Hallidie type of tram is nearly double that demanded by the Bleichert system, and, in the second place, the capacity of the former is limited to, say, 75 tons per day of ten hours, while the essential construction of the latter permits of a capacity that, even over a mountainous country, ordinarily reaches from 250 to as much as 400 tons per day.

The cost of a tramway of this kind depends, of course, upon the nature of the ground over which it is to be built and the distance from a railway terminal. In the high altitudes of Colorado to-day the cost of material for an installation having a capacity of 200 tons per day of ten hours would be about $2.10 per foot of tram line, and the cost of freight, plus erection, would be about $1.15, so that the total cost would be about $3.25 per foot. A tramway, one mile long, having the capacity mentioned, would entail the expenditure of about $20,000. As a matter of hard fact, the writer is



A CABLEWAY WITH 2100-FOOT SPAN AT OURAY, COL. ERECTED FOR THE AMERICAN GOLD MINING COMPANY BY THE A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

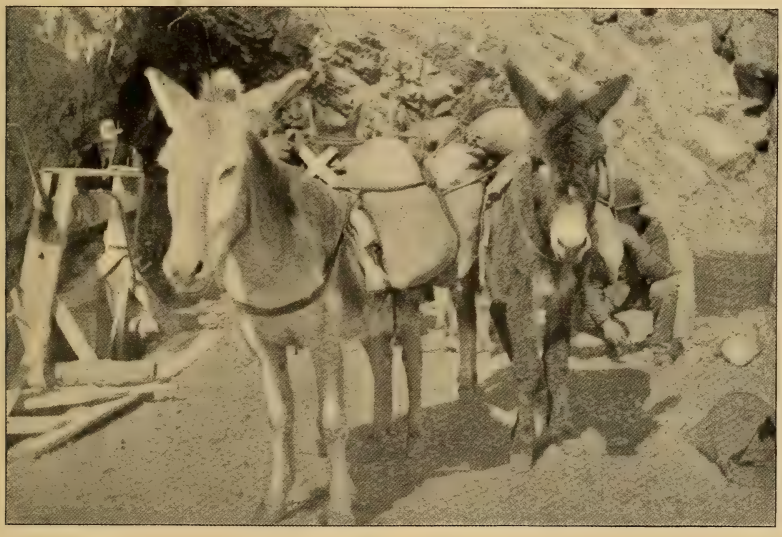
aware of the expenditures made on several tramways, the first cost, as measured per foot, ranging from $2.50 to $5.50, and there is no doubt in his mind that the most expensive were usually the cheapest in the long run on account of the notable difference in costs of maintenance.

Among several interesting installations in the San Juan region the Silver Lake tramway is remarkable on account of having one span which clears a length of 2200 feet. In a distance of 8400 feet and in a vertical descent of 2100 feet there are only nineteen supports. One of the best installations in Colorado is, I think, that of the Camp Bird mine, near Ouray. This Bleichert tramway connects the mine with the mill, the distance being 9000 feet and the descent 2100 feet. The stationary cable on which the buckets travel is a locked

wire rope having a diameter of 1⅛ inch on the down side and 1 inch on the other, which carries the returning empties. The traction rope to which the buckets are attached has a diameter of ⅝ inch; it has a hemp centre, to make it pliable, and is made of nineteen separate wires. Each of the buckets, of which there are forty-six, carries 750 pounds of ore. They travel at the rate of 350 to 450 feet per minute. Under these conditions the tramway has a capacity of about 120 tons in ten hours, but both speed and number of buckets can be increased without danger, so that the capacity could be 450 tons per twenty-four hours.

The cost of transporting the ore, in this case, with an output of 3100 tons per month, is fifteen cents per ton, but this includes the carriage to the mines of supplies of all kinds which are loaded into the empty returning buckets. This feature of mountain tramways is most important, because during several months the trails are often impassable by reason of snowdrifts. During such times the tramway takes up all necessary supplies, and occasionally even the manager may find it the safest way of reaching the mine.

The operation of mines which are accessible with difficulty has been much facilitated in this way and also in another manner which is thoroughly in keeping with the advance of the industrial arts elsewhere; I mean the utilisation of the power of the mountain torrent through the medium of electricity. So long as the direct current was used, the transmission of power had narrow limitations, because under that system the practical limit was 700 volts, and it was not possible to augment this by the use of transformers. Since the introduction of the alternating current these limitations have been removed and the voltage can be raised to an extent limited only by the insulation of transformers, although in practice the voltage is usually raised so that the power can be transmitted over a wire nothing smaller than No. 5, because that size gives the lowest relative investment in copper.



ORE CARRIERS

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The direct current and the alternating systems can be compared by stating that 2000 volts transmitted by the latter system would require only one-sixteenth

of the amount of copper that would be needed by 500 volts transmitted by the former per horse-power per given distance and at a given loss. The usual cost of power, as sold by the large power plants to the mines at timber line, is $8 per H. P. per month.

The result of man's enterprise may sometimes be measured in units of money, but there is much that cannot be expressed by any known standard of value. Up there on the mountain side a great mine is yielding its tribute of gold-bearing rock; down yonder the ponderous mechanism of a mill is filling the valley with the deep thunder of its voice; connecting them is the silent tramway, threading hill and vale with undeviating line,—these, indeed, are tangible. But, one may ask, what of the daring, pluck, and tireless energy of the prospector who first penetrated these mountain fastnesses and fought his way amid the unrelenting snows? What of the faith, born of sure knowledge, which enables the engineer, with the eye of the constructive imagination, to see the whole installation of the mine, tramway, and mill long before he built them? These are not measurable. Yet for that very reason they appeal to us with a touch of romance which lightens the sordid seeking for gold with a light like the sunset glow on a winter day. It is my belief that more hardships were faced and more dangers encountered in the early explorations among the mountains of the San Juan, in Colorado, than amid the whole length of those foothills of California, which have become illumined, now and forever, by the romance of Bret Harte.

LIQUID FUEL FOR SHIPS

ITS ADVANTAGES AND DISADVANTAGES IN WAR AND MERCANTILE VESSELS

By Sir J. Fortescue Flannery

THE problem that confronts every designer of a warship, as stated recently by the writer in addressing the Institution of Naval Architects, is the combination of the greatest speed, armament, and ammunition supply, protection, and range of action, in the smallest and least expensive hull. Any reduction of weight and stowage room of any of the necessary elements of any of these qualities is a saving which acts and reacts favourably upon the problem.

The practical figures of comparison between coal and oil fuel realised in recent practice are that two tons weight of oil are equivalent to three tons weight of coal, and 36 cubic feet of oil are equivalent to 67 cubic feet of coal as usually stored in a ship's bunkers; that is to say, if the change of fuel be effected in an existing war vessel, or applied to any design without changing any other of the data than those affecting the range of action, the range of action is increased by 50 per cent. upon the bunker weight allotted, and nearly 90 per cent. upon the bunker space allotted.

The coal protection for cruisers, whatever its real advantages,—a matter upon which different opinions exist,—would disappear with the use of liquid fuel, because it would be, for the most part, stowed below the water-line, if not wholly in the double bottom. The double bottom and other spaces, quite useless except for water stowage, would be capable of storing liquid fuel, and the space now occupied by coal bunkers would be available for other uses. The ship's complement would be reduced by the almost complete abolition of the stoker element and the substitution of a limited number of men of the leading stoker class to attend to the fuel burn-

ers under the direction of the engineers, and the space of stokers' accommodation, the weight of their stores, together with the expense of their maintenance, would be saved. The number of lives at risk, and of men to be recruited and trained over a long series of years would be reduced, without reducing the manœuvering or offensive or defensive power of vessels of any class.

Rebunkering at sea,—so anxious a problem with coal,—would be made easy, there being no difficulty in pumping from a store-ship to a warship in mid-ocean in ordinary weather; 300 tons an hour is quite a common rate of delivery in the discharge of a tank steamer's cargo under ordinary conditions of pumping. The many parts of the boiler fronts and stokehold plates, now so quickly corroded by the process of damping ashes before getting them overboard, would be preserved by the action of the oil fuel, and the same remark applies to the bunker plating, which now so quickly perishes by corrosion in way of the coal storage.

Liquid fuel, if burned in suitable furnaces with reasonable skill and experience on the part of the men in charge, is smokeless. It is easy to produce smoke with it, but this is evidence of its being forced in combustion, or of the detail arrangements of the furnace being out of proper proportion to one another. In regard to smokelessness, oil fuel, when used under conditions customary in the merchant service, is not inferior to Welsh coal, and superior to any other coal ordinarily in use. The cost of fuel in the East is less than that of Welsh coal when the cost of transport and Suez Canal dues are added to the original price of the coal as delivered in a Welsh port.

The evaporative duty required from the boilers of destroyers is greater than that required for boilers of any other type, and, whilst it is possible to burn enough liquid fuel to produce the required duty in boilers hitherto using coal as natural draught, or even coal at moderate forced draught, difficulty has been found in burning enough oil fuel in boilers of the destroyer type to produce the same duty as that realised under coal at great air pressure. The question of economy of fuel in destroyers when at full power is of comparatively little importance, but the production of the maximum power is essential; and further experiments now in process will probably solve the difficulty, as it has been solved in locomotive practice on the Great Eastern Railway by the skill and enterprise of Mr. Holden.

Messrs. Yarrow have obtained some highly encouraging results in two torpedo-boats built by them for the Dutch Government. Their process is to obtain the maximum speed with coal under all usual conditions of forced draught, and then to inject liquid fuel into the furnace above the coal, thus securing additional boiler duty, while leaving the whole of the grate surface available for coal combustion. The result was to increase the maximum speed of the vessel by over one knot per hour. Messrs. Thornycroft have recently made experiments, and have obtained the high evaporative duty of 18.95 pounds of water per pound of oil fuel. The extra rapidity of raising steam with liquid fuel is undoubted, and this is a feature upon which much stress has been laid in recent naval debates. So far as experience has shown there is no deterioration of liquid fuel, however long it is stored before use.

The conditions which fuel must fulfill in the case of a mercantile vessel differ only in some respects from the conditions applying to a war vessel, the chief difference being that of cost. The question of direct cost is of little importance in a war vessel, provided the advantages above named are really secured in practice; but in a commercial vessel the direct cost of fuel, although here also necessarily merged in other questions, is of the first importance. The saving of stokers is considerable, although the complement should not be reduced below that necessary to assist the ship's engineers in overhauling, or in case of emergency. In some instances a stoker's and trimmer's crew of thirty-two is now represented by a fireman's crew of eight hands, whose duty, however, is

mainly cleaning and helping the engineers with their greasing.

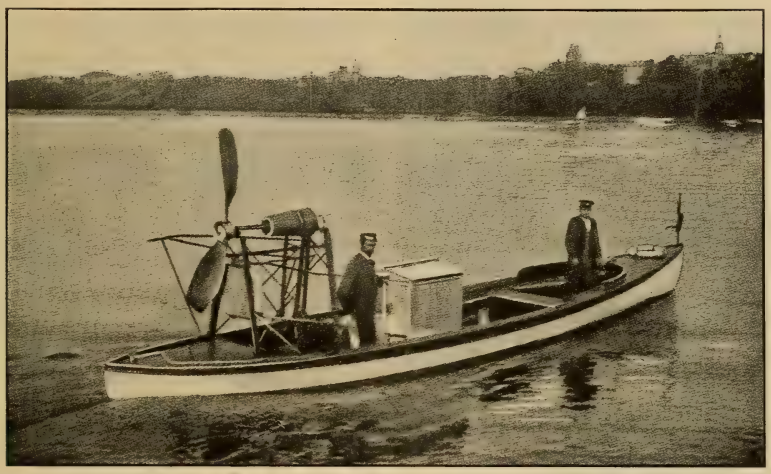
In the case of medium-sized vessels working with natural draught the advantages of uniform steaming, irrespective of wind and ventilation, and of large reserve of steaming power, are the same for liquid fuel as for every other system of forced draught. The greatest commercial gain, however, is the increase of weight and space available for freight. Adopting the proportion of 3 tons coal as equal to 2 tons oil fuel, we find a gain in weight of, say, 1000 tons in the freight of a first-class Atlantic steamer, and a gain of nearly the whole of the bunker space, which, subject to drawbacks of non-stowage in the hot parts of the bunker space, would be available for measurement freight. Allowing for these, and assuming the storage of the whole of the fuel in the double bottom and peaks, there would be a gain approaching 100,000 cubic feet of measurement made available for freight in such a vessel. The gain from substituting the new fuel in vessels of less steam-power proportionate to the size would be correspondingly reduced, but it may be fairly estimated for most ships that 25 per cent. of the space now occupied by coal bunker storage could be utilised for cargo by the transfer of the fuel in a liquid form to the double bottom and other parts not now of any direct use.

The cleanliness of oiling instead of coaling passenger ships, and the saving of detention at ports of call are obvious. The provision of storage and pumping and ventilation arrangements and of the furnace gear are a disadvantage both as regards cost and weight, and in some ships trouble and expense has arisen from boiler leakage consequent upon the presence of water in the oil and the lack of experience of the engineers; but these difficulties are now disappearing, and latest developments are in the direction of simplicity and less first cost. Oil fires do not require cleaning, thus avoiding a prolific source of lost speed in ordinary voyage routine.

Current Topics

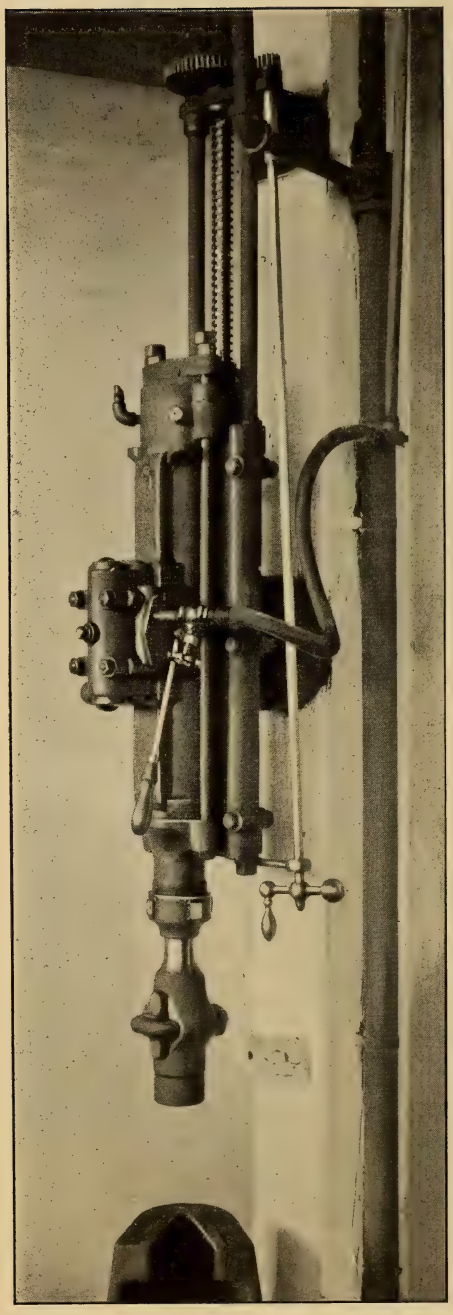
By far the most novel exhibit shown at the recent German motor launch exhibition on the Wannsee, at Berlin, was a boat depending for its propulsion upon an air propeller, thus presenting in concrete form an idea which for the past ten years has been periodically bobbing up. The boat was built for Count Zeppelin, of airship fame, primarily for experimental investigation of the most suit-

able shape of propeller for driving his aerial craft. It is about 40 feet long and of 6½-foot beam, and can hold fourteen people. Power is furnished by a 12 H. P. Daimler benzine motor which transmits it to the air propeller of aluminium, mounted at the stern on a frame about 6½ feet high, as shown in the annexed illustration. No particulars are given of the performance of the unique vessel, but it is safe to say that its chief claim to consideration depends upon its novelty.



A BOAT WITH AN AIR PROPELLER

MARCONI continues to keep, or be kept, before the public eye. The latest peg on which his critics have been able to hang an accusation was put up by Marconi himself when he applied to the British patent office for permission to change an application for a new form of coherer, which he had filed in some other name, to an application for an invention communicated to him by Solari, of Italy, to cover a coherer known as the Italian navy coherer. On the strength of this his opponents have intimated that this was tantamount to an admission that all of his devices were the inventions of others. It has also been asserted that it was by means of this coherer, together with the employment of a telephone receiver, that Marconi was enabled to receive those famous long-distance signals from Poldhu. Although many of Marconi's earliest patents were for improved forms of the Branly coherer, it is evident that this form is likely to be superseded by auto-de-coherers, that is, coherers that require no tapping. The Solari coherer is of this type. Briefly, it consists of two small carbon rods within a tube, and between the inner ends of these rods two drops of mercury are placed, separated by a small iron cylinder. Another auto-de-coherer which Marconi has recently described is one in which he employs the well-known action of electric oscillations in reducing the effects of magnetic hysteresis in iron, causing the metal thereby to respond readily to any influence which may tend to alter its magnetic condition, as Professors Gerosa, Finzi and others have pointed out. To avail himself of this action Marconi uses a small induction coil having for a core an endless rope of iron wires which, by clock-work, is caused to move slowly past two horseshoe magnets. The ends of the wire of the coil next the iron core are connected to the vertical wire and ground, respectively; the terminals of the other wire of the coil are connected with a tele-



A ROCK DRILL ARRANGED AS A PNEUMATIC HAMMER BY THE RAND DRILL COMPANY, NEW YORK

phone or other suitable receiver. When electric oscillations traverse the vertical wire, rapid changes of magnetism of the iron core result, with consequent induced currents in the coil, of sufficient strength to be heard in the telephone. It is stated that a speed of thirty words a minute, as against ten or twelve with the tapper coherer, has already been reached with this magnetic auto-decoherer. Since the announcement concerning this coherer was made Mr. E. Rutherford, whom Marconi credits with having done pioneer work in this direction, has written to the technical press, claiming that he has also employed an endless band for this purpose, and intimates that Marconi has apparently applied to the method the principle used by Poulsen for recording telephonic messages. Because of all this certain people doubtless appreciate that uneasy lies the head that wears the inventor's crown.

By the way, it is now the better part of a year since Marconi received the letter S at Newfoundland from Poldhu, which gave rise to the carefully nurtured hope that within a very short while the regular transmission of wireless messages across the Atlantic at six pence per word would be an ordinary occurrence; but as yet there seems to be no immediate prospect of the realisation of this hope. The latest information on the subject appears to be that Marconi is to be taken to the shores of Canada in an Italian warship for the purpose of sending or receiving the very first regular transatlantic message by his system.

Of the use of a rock drill as a blacksmith's hammer, doing away with one or two helpers in the shop, a correspondent at one of the mining districts writes to *The American Machinist* as follows:—"The drill, minus the tripod, was fastened to a vertical support. An ordinary anvil was fixed in a position under the ram, and the necessary connections for compressed air were made with the cylinder. When a blacksmith has some heavy hammering to do, he

has some one, as usual, to manage this contrivance, while the smith takes care to have the blows struck in the proper place, as with a steam hammer, except that the blows are not as heavy, but more numerous for a given space of time. At the time that I saw this improvised steam hammer in operation the blacksmith was working down a piece of steel or wrought iron, about 3 inches wide at its widest part, 1 inch thick at its thickest part, 2½ feet long, tapering in both width and thickness, and the hammer appeared to be doing excellent service. It appeared to me a very simple, effective and quite inexpensive apparatus, especially considering the fact that, excepting the hammer head, it was rigged up from material to be found in any mining outfit, and that it could be very easily resolved into its original parts and their former duties resumed, since neither drill nor anvil suffers any from this somewhat unusual use." To this it may be worth adding that one of the prominent makers of rock drilling machinery show among their specialities a large rock drill arranged as a pneumatic hammer and corresponding in all respects with the contrivance above mentioned. An illustration of it is given on the opposite page. The same company direct attention to a rock drill converted into a drift bolt driver, built primarily for driving such bolts into the timber construction work of caissons. This, as ordinarily done with sledge hammers, is slow and expensive, and the power hammer in question has been found to excellently serve its special purpose. It has handles so arranged as to be conveniently managed by two men who place the anvil of the machine, which has a cupped end, on the head of the bolt to be driven and start the machine. Pneumatic power does the rest.

THERE was a strike on among the machinists, so the story was told the other day, and one of them thought it would be a good time to paint his house, so he held a consultation with a local painter which resulted in the appearance of the latter with his kit at the home of the machinist. He put up his ladder and proceeded to go to work. At this juncture the machinist appeared, and he, too, mounted the ladder, and, taking up a brush, began to paint. He was stopped by the painter, who demanded if he were a member of the painters' union. "Of course not," said the machinist; "why?" "Because if you are not you cannot paint with me," said the painter. "Get out of here," yelled the angry machinist; "I'll be damned if I'll stand any man telling me what I can and what I cannot do around my own house."

THE contractor for the building of the New York rapid transit subway recently made the somewhat startling statement that owing to the great developments of the electrical art now going on, a generation of electricity was not now over three years, whereas when he had originally figured on the work it was considered to be at least seven years. The great advance in the design and construction of an electrical equipment for the production and utilisation of electric power for tractive purposes has enhanced the cost of equipment to such an extent that although the contractor in question had engaged the best electrical engineering talent in the preparation of his original estimates, he now finds that the actual cost for the equipment will exceed the estimate by many millions of dollars. This experience, however, is not altogether peculiar to electric traction equipments, for there is probably no large electric light or power company in existence, with operations extending back over fifteen or eighteen years, that has not found it essential to change its entire system two or three times in that period.

THE telephone exchanges especially have undergone repeated radical changes in the period mentioned, so much so that an immense quantity of perfectly operative apparatus has been thrown

into the junk heap to make way for improved and generally more economical methods of operation. In one case alone, in the city of New York, telephone apparatus to the value of $400,000 was for this reason deliberately dumped into the junk pile. It is also fresh in the minds of the American investing public how the traction companies of New York at enormous expense changed, in a few years, from horse-power to the cable system and then to the underground electric traction system. In addition to the losses which these various changes in the methods of operation have involved, enormous expense has also been incurred in the larger cities by the substitution of the underground in place of the aerial system of conductors. This change in the case of the telephone company operating in New York city entailed a loss equal to three-fifths of the entire net earnings of the company since its organisation. The only electrical industry, it may be remarked, that has not suffered in the past twenty or twenty-five years from radical changes in the methods of operation is the telegraph, the losses of this general nature here having been confined to the change from aerial to underground wires in cities. This fact has given the impression in some quarters that the telegraph companies are not progressive, and loud demands have been made upon those companies to adopt some of the many systems of rapid machine telegraphy whose inventors are clamouring for recognition, the fact being lost sight of, or ignored, that the methods now in vogue in telegraphy are, it may be said, specimens of the survival of the fittest. Machine telegraphy from the earliest days has been tried and, in numerous respects, found wanting.

THE advocates of municipal ownership of public utilities, like the telephone, electric lighting, etc., are sufficiently active in the United States to cause the managers of those industries a good deal of uneasiness. It is one of the stock arguments of the advocates of such ownership that the various plants can be operated by the municipalities at a cost from 25 to 50 per cent. less than is charged by the private owners of such plants. This argument is usually based on the figures obtainable from the reports of electric light, power, and telephone companies as to the cost of operation, which figures frequently do not include taxes, interest on bonds, or depreciation. It has, therefore, been proposed before more than one convention of the representatives of these industries that a more uniform method of preparing reports be adopted by the different electrical companies to the end that more accurate information relative to actual expenses of operation and maintenance of such systems may be disseminated. Having this object in view, among other features which, it is urged, should be included in maintenance, is a reserve fund to meet the depreciation in the value of the assets of a plant due to improvements of the art, which proposition cannot be regarded as unreasonable when it is considered that, as shown in the preceding paragraph, this depreciation has frequently amounted to 100 per cent. of the value of the property in a single year.

WHAT was recently called in headlines by the German press "The Catastrophe in the Schuckert Electrical Company" has recalled public attention sharply to the conditions under which some of the great electrical corporations of Germany were promoted, and the embarrassments which some of the methods employed have more or less inevitably entailed. The event alluded to, as reported by Consul-General Frank H. Mason, at Berlin, was a meeting late in July of the stockholders of the Schuckert Electrical Company, at Nuremberg, at which the managers announced that, through depreciation of plant and material, insolvent accounts, and necessary appropriations for a reserve fund to meet further depreciations, the company had suffered losses aggregating 15,500,000 marks. As the

Schuckert Company is one of the foremost corporations of its class in Europe, with an up-to-date plant and all the accompaniments of a large business, some surprise has been expressed that its affairs should make such a bad showing for its shareholders. The explanation leads back to the fact that the sudden rise of some of the German electrical companies into corporations of vast resources and activities was, in some cases at least, the result of skillful and artificial creation of markets for products rather than the supply of an actual and legitimate demand. Concisely stated, some of these companies bought their orders for electrical installations and materials by financial operations that left them shareholders in many enterprises which have since proven less promptly lucrative than had been hoped, and have thus drawn more or less heavily upon the capital of the parent companies.

To understand how all this came about, it should be remembered that German progress in electrical science was for a long time far in advance of popular appreciation of its advantages. The companies organised and equipped for the manufacture of lighting and power plants could not wait for the slow growth of public demand for such improvements, and they therefore undertook to finance and erect such installations themselves, confident that, once established and in use, the public would not fail to appreciate them and invest in their securities. This went very well for a time. It created a large and ready market for electrical machinery and materials at high prices, and supplied hesitating municipalities with electric tramways and lighting plants which their citizens greatly enjoyed, but which were built and for a time managed by the electrical manufacturing companies at their own expense. Inevitably this process of consuming their own capital necessitated heavy loans and frequent increases in the stock of such corporations, together with a steady expansion of their manufacturing capacity. Some of the companies, especially the Schuckert corporation, made enormous investments in electric installations for the manufacture of calcium carbide, putting in the machinery at their own prices, but receiving for it little or nothing except stock in the carbide plants. Thus the supply of acetylene material was soon far beyond all legitimate requirements, prices collapsed, and the carbide industry suffered a serious and permanent reverse.

Another heavy blow for some of the German electrical manufacturing companies has been the failure of the storage-battery traction system for tramways, which is now conceded to be practically hopeless. When electric traction was introduced into Germany municipal governments were timid and hesitating. They objected to the overhead conductor because it was considered unsightly and dangerous, and in order to obtain any franchise at all the tramway companies and the electrical manufacturers who were behind them had to agree to furnish cars that would dispense with a visible trolley. This meant either the underground-conduit system,—which is so expensive to construct as to be justified only by a very heavy traffic,—or a reliance upon storage batteries, and the companies generally had recourse to the latter. The extent to which this has been done may be inferred from the fact that one company in Hannover has at present 274 accumulator cars in service. There, as at Halle, Hagen, and many other places, they have been found so heavy, costly, and subject to trouble from battery gas explosions as to be unremunerative. At Berlin, where many hundreds of them have been in service, all are to be abandoned and recourse had to underground conductors for centrally located streets, and overhead wires for the less crowded and suburban sections.

The net result of all these conditions was that some of the electrical manufacturing companies of Germany which had

gone on organising and supplying power, lighting, carbide, and other plants, not only in Germany itself, but in Russia, Scandinavia, Austria-Hungary, and other European countries, were caught with all sail spread by the adverse gale that set in during the summer of 1900. In the stormy weather that ensued most industrial stocks declined sharply, the investing public became alarmed and timid, the failures of the Leipziger and other banks followed a few months later, and led on to the situation of which the recent meeting at Nuremberg has been the ultimate result. The encouraging features of the present condition are the fact that the credit of several of the oldest and strongest of the electrical companies remains unshaken, the general feeling that the bottom has been reached, that the obligations entailed by a system of forced development have been mostly liquidated, and that with the good cereal crops that will be harvested this year, peace throughout the world, and the hoped-for renewal of the commercial treaties which are to lapse next year, the foundation will be laid for a renewed and enduring prosperity.

A PECULIAR phenomenon has been noted by Professor F. W. McNair, at the deep shaft of the famous Tamarack copper mine. Two plumb lines, 4250 feet long, were hung down this shaft. The bobs were 50-pound cast-iron weights, and hung from No. 24 piano wire in pails of cylinder oil. At the top the two wires were 16.32 feet apart, whilst careful measurement at the bottom showed them to be 16.43 feet apart, so that the two wires, supposed to be plumb, were not parallel. The shaft was carefully explored for obstructions, and the position of one of the wires was shifted so that the two hung 17.58 feet apart at the top; but measurements at the bottom again showed a deviation, the two there being 17.65 feet apart. Lead bobs were next tried, and other wires, but similar results were obtained. After many experiments, the conclusion finally reached was that the deviation was due to air currents, since by closing in the top of the shaft and other openings into it, so as to impede the circulation of the air, closer agreement was obtained between the top and bottom measurements.

ONE hears a good deal nowadays about how money is saved in different manufacturing processes by improved machinery and methods. That such savings are altogether real need not be doubted; but they suggest several very practical questions which probably in many cases are not thought of and remain unanswered. What, for example, becomes of those savings? Where are they when the year is up? What has one got to show for them? Apropos of this, W. Osborne, who, under the head "Echoes from the Oil Country," contributes to *The American Machinist* every week a letter full of interest and good sense, in a recent issue of that journal told a little story which is well worth repeating. It appears that a firm, situated in the heart of a busy city, was crowded for room, and had done quite a little experimenting in efforts to improve on their power plant. For years they had used steam, and the engine and boiler were located underneath the shop, which was a combination of machine shop, blacksmith shop, and woodworking shop. As things became more crowded the cellar became a place difficult to get to. It was hard to get coal down and just as hard, or harder, to get ashes out. Besides that, it was a dark, poorly ventilated place to ask a man to stay in, and it was hard work to climb up a little winding stairway between firings to get fresh air.

As a means to save room, expense, and trouble, an electric motor was tried. This did not prove altogether what was desired, and finally a gas engine was put in. This, after they had become a little acquainted with it, seemed to fill the long-felt want in fine shape. As

the gas engine was not then nearly so common as it has since become, one of the owners used to be at some pains to explain its workings and virtues to visitors. On one occasion he had been entertaining a missionary society that was connected with the church he attended. After dinner the party was taken through the shops. Coming to the gas engine, their host explained its workings at some length, winding up with the statement:—"Using it instead of steam saves us $1300 a year."

"And what do you do with it?" asked a bright young lady of the party.

"We run the shop with it. It furnishes the power for everything upstairs. The wind in the blacksmith shop is made by it. Everything you saw turning around in the works is turned by it. You see we save room. We save in attendance, and we save in fuel. We save in getting the fuel in and the dirt out. It is a great thing for us in our business. You can see that, for it saves us $1300 a year." And he bowed cheerfully to his fair questioner.

"Now, that is very nice," she replied. "I am glad to hear it. And what do you do with it?"

THINKING he had not made his meaning clear to one not likely to be at all familiar with shops and shop ways, the shop owner very patiently went over the ground again, telling how it was necessary to have some means of getting motion, telling of their use of the various methods, giving the advantages and disadvantages of each, and, after having done his best, he wound up with the strong point of the saving caused by his last method.

"That is very interesting, very interesting indeed; and what do you do with it?" asked the young lady once more.

With a strong effort to think of a way to put the matter in a simpler form, he began again:—"You know it is necessary for us to have something to run our shop to make the wheels go round——"

"Yes, yes, I see all that; but what do you do with the $1300 you save every year?" And the young lady looked around in an inquiring way as though expecting to see it stowed away somewhere. Mr. Osborne says that he is not sure how the owner of the shop explained that part to her, but when he told it to him, they had a good laugh together.

"IT seemed very real, that $1300, the way she spoke of it," said he; "but, really, while I can figure that we have had that much less to pay for fuel, wages, and so forth, still it seems just as hard to be ready for pay-day and to find money to pay the bills as ever it did. Perhaps you have had experience enough to be able to tell me how to get my hands on it."

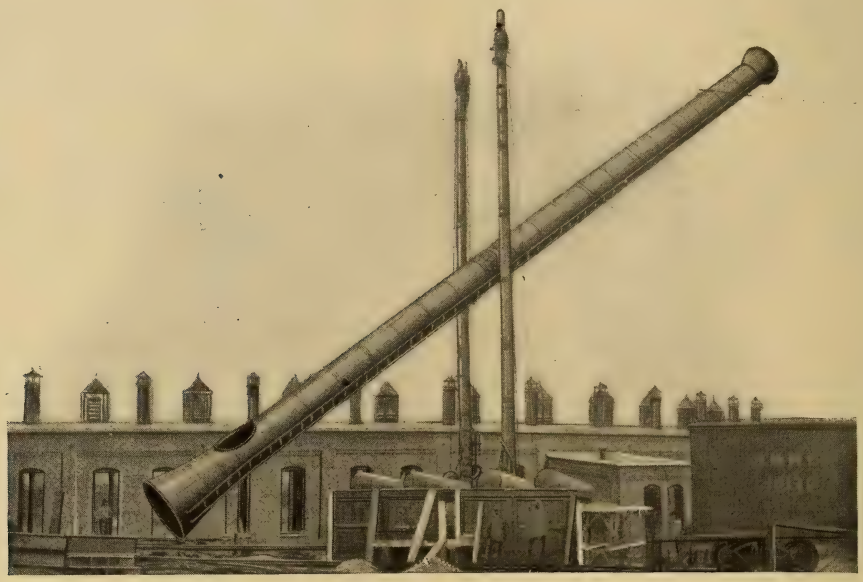
Mr. Osborne's experience had not been varied enough to be of much use. With all his efforts in the way of shop economies, he had never lain awake at night thinking how to best take care of the money that they saved.

"I told him," concluded Mr. Osborne, "I would willingly pay the freight on any surplus he might be troubled in finding room for, and I am willing to hold that offer open against all comers. If anyone with experience in changing such things from figures to facts with reasonable certainty will kindly send me the rule, I will do my best to commit it to memory, and will gladly send a 'vote of thanks' in return."

GAS made from peat appears to have been employed as fuel at the Motala Steel Works in Sweden for the past thirty years, originally for the puddling furnaces, and to a still greater extent, subsequently, for the open-hearth furnaces. The peat is got chiefly from the further side of Lake Wetter, across which it is brought in sailing vessels and unloaded direct into large storehouses, whence it is forwarded to the gas producers. The yearly consumption is from 13,000 to 16,000 cubic yards of dry kneaded peat. Two large gas producers are used, from which the

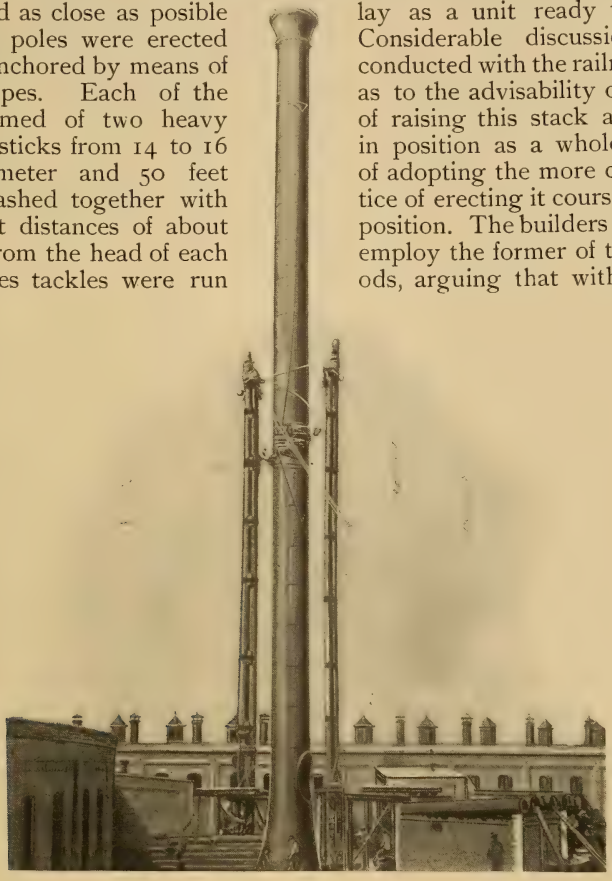
gas is led to the open-hearth furnaces through a condenser for ridding it of some of its moisture. Although the peat gas, owing to the distance the peat has to be brought, is dearer than coal gas, it is used preferably in most Swedish steel works in consequence of the insignificant amount of sulphur and phosphorus it contains. In the rolling mills there is a smaller peat gas producer for one of the plate furnaces, and thin steel plates especially scale less in rolling when the furnace is fired with peat gas. The use of peat gas in the Swedish steel industry contributes largely to enhance the quality of the steel, irrespective of the cost of fuel, becoming thereby often higher than with coal. The choice of the fuel, however, is not always determined by its cheapness so much as by its influence upon the material produced.

THE usual method of erecting steel smoke stacks is to build them up in short sections on the spot where they are to stand. In the case of a stack of this kind recently constructed by the Franklin Boiler Works Company, of Troy, New York, for the West Albany shops of the New York Central Railroad, this method, however, was abandoned for the novel plan of raising the entire stack into position at one time. The stack is 140 feet in height, with a diameter of 10 feet at its base, tapering to 5½ feet about 12 feet above the base. It weighs approximately 16 tons exclusive of the base plate, or 21 tons in all. An ornamental copper top 6 feet high relieves its otherwise too severe appearance, and a light ladder runs from the base over the top. The way in which the work was done is told most graphically by the two illustrations, on this page and the one opposite, reproduced from photographs kindly supplied by the contractors. To these *The Iron Age* adds the following account:—At the builders' shops the stack was rivetted in 30-foot lengths. These lengths were loaded on flat cars and conveyed to the exact location desired, a temporary track having been laid to the site. While the stack was being made at the shops a concrete foundation was being laid for it,—10 feet



A NOVEL METHOD OF ERECTING A STEEL SMOKE STACK

in depth, and with eight anchor bolts, 2½ inches in diameter, imbedded in proper position. The base plate was then placed in position. On the east and west sides of the concrete foundation, and as close as posible to it, two gin poles were erected and securely anchored by means of heavy guy ropes. Each of the poles was formed of two heavy trimmed pine sticks from 14 to 16 inches in diameter and 50 feet high, firmly lashed together with 1-inch ropes at distances of about 18 inches. From the head of each of the gin poles tackles were run through quadruple blocks and down to similar blocks at their bases, ready to be attached to the stack. Each of the 16 strands thus obtained was easily capable of raising a ton.



READY FOR THE BASE PLATE

Upon the arrival of the stack in sections, unloading was commenced, beginning with the top section and following this with each of the lower ones in regular order. As the sections were unloaded they were moved along cribbing extended from the car track over the stack foundation and between the gin poles. The ornamental top was then put in place, and the sections were riveted together until the entire stack lay as a unit ready to be raised. Considerable discussion had been conducted with the railroad company as to the advisability of the method of raising this stack and putting it in position as a whole, rather than of adopting the more common practice of erecting it course on course in position. The builders determined to employ the former of the two methods, arguing that with proper care no increased risks would be entailed, and that a shop-built stack was always preferable on account of the superiority of hydraulic riveting and the better opportunities offered for examination and inspection of the work while in progress. As soon as all was ready for the raising, a careful final inspection was made, and then the great blocks were attached to numerous hemp cables stretched around the stack just above the centre of weight. The signal was given to two gangs of men, one on each of the winches near the base of the gin poles, the cables

tightened and gradually the top began to leave its horizontal position and move upward. As it rose, a gang of men began to make preparations for pushing the lower end into place over the base plate.

DURING the early part of the raising an accident occurred, which, had it come later, might have been serious. The upper end had risen about 20 feet when, without warning, one of the strands of rope forming the hoisting tackle on the west gin pole parted. Immediately the stack fell back to its horizontal position. Fortunately, in falling, the ladder attached to the outside of the stack had been turned underneath. The ladder struck first, in this wise breaking the shock and saving the stack proper from any injury whatever. Of course, the ladder was badly bent, and the ornamental top slightly dented. These defects were soon remedied, and a few days later the second attempt at raising was made. This was entirely successful. Gradually with straining cables the great stack rose to the perpendicular, and was fitted over the base plate, to which it was firmly riveted. After careful adjustment the tackles were withdrawn and the work was completed. One entire day was consumed in raising the stack, and part of another in adjusting it. The saving in time and labour made by the builders fully justified the method and stamped the work as a complete success. It is interesting to note that under all of the strain of raising, the deflection of the stack itself was scarcely noticeable.

TRACTION increasers for locomotives have, of late, again come into prominence. Their object, as their name implies, is to make available at certain times, when necessary, the whole weight of the engine for tractive power, by throwing it all upon the driving wheels, —in starting, for example, and for heavy pulls over critical portions of a line,— only the normal weight on the driving wheels being used elsewhere. Referring to this kind of apparatus recently, the *Railroad Gazette* remarked that the time has come when it should have serious attention from the designers and users of locomotives. If it rests on fallacies, the sooner those fallacies are recognised the better; if its usefulness is greater than the sum of the objections to it, that fact ought to be ascertained and made plain. A contrivance which has been repeatedly tried and abandoned in the last sixty-seven years is, on its face, subject to scrutiny.

IT is apparent that if a locomotive is fitted with the traction increaser, a device is placed within the control of the engineman which enables him to increase the weight concentrated on the driving wheels of his locomotive beyond what is assumed as normally safe for the line. There is no assurance that the device will not be used at points where it would be objectionable, as, for instance, on bridges, on soft track, and on sections of road having light rail. The tendency of the engineman would be to take advantage of it often, just as the tendency is to work live steam in the low-pressure cylinders of compound locomotives, notwithstanding the injurious effects of such practice. There is no adequate means of controlling this when enginemen are not under the eyes of a road foreman. If it assists the engineman in getting over the road, he will use it as often as he dares, and it is believed that broken or bent rails and strained bridges would be likely to follow its use.

A CERTAIN weight carried on the leading truck is necessary for its efficiency. The design of the locomotive should be such that the truck does not carry an excessive weight or a weight considerably beyond that necessary to give it the adhesion for properly guiding the engine. If, therefore, a considerable amount of weight is withdrawn from the truck, to that extent it becomes

an idler, and the duty of guiding the engine is transferred back to the rigid wheelbase. The conditions then are approximately like those of a switching engine, without trucks, and with a long over-hang front and back. To work such an engine as a road engine at considerable speed may become dangerous, and would certainly increase the injurious effect of the engine upon the rails. If, concludes the *Railroad Gazette*, a locomotive is cylindered to suit the normal weight, it will be under-cylindered for the additional weight resulting from the traction increaser; if cylindered for the maximum weight, the cylinders will be too large for economical running under normal conditions.

SELDOM has the international iron trade presented a more peculiar aspect than at present. Conditions of two years ago are practically reversed. Beginning in the East, Russia is suffering from what approaches a complete collapse. Germany is slowly recovering from a period of small trade and low prices. In Belgium, Austria, and France the iron trade is in what may be called a normal condition. Great Britain is again appearing as an exporter to America on a large scale. It is true that the profit realised by this export business is extremely modest, but the fact that it can be done at all, with dear raw materials, excessive railway charges, and unimproved plant, is encouraging. America is the centre of attraction. Her industrial development is unprecedented, and is second only to her demand for material. In spite of a production of iron which promises to be little short of 18,000,000 tons for the running year, and in spite of the present considerable imports of iron and steel from Great Britain, Belgium, and Germany, the urgent requirements are not filled. Under the old conditions of unrestricted competition we would be sure of a rapid and ruinous rise in prices, defying all calculations, and followed by a disastrous and sudden drop. Is it that the steadying influence of the great manufacturing corporations will continue to be sufficient to save the world from these too sudden fluctuations? We must hope it will.

IT would be a dangerous mistake to hope for any permanency of the present situation. Some 5,000,000 tons of blast furnace capacity is rapidly nearing completion in the United States. Manufacturing cost is not going up in proportion to the now ruling prices, and as soon as the present temporary and most extraordinary demand is relieved, the United States will again be in position to plane and pave the way for the coming export trade in iron and steel which is the dream of the nation, and the only permanent outlet for the enormous output.

ELIPHALET W. BLISS

A BIOGRAPHICAL SKETCH

ONE of the number of distinguished engineers and manufacturers who, on the occasion of the visit of Prince Henry of Prussia to the United States last February, were selected to meet him as representative of American industry and enterprise, was Eliphalet W. Bliss, long prominent as an inventor and maker of presses, dies, and special machinery for working sheet metals; sole manufacturer of the Whitehead torpedo and appliances for the United States Navy, and president of the United States Projectile Company. The por-

trait of him which is presented in this issue is an excellent likeness of very recent date.

Mr. Bliss began his business career as an apprentice in a country machine shop, in the northern part of New York State, when a boy, serving in that capacity five and a half years, afterwards being connected with the Parker Gun Company for several years at Meriden, Conn., and then coming to Brooklyn and working for the Campbell Printing Press Company. Industry and close application were characteristic of him from the beginning, and it was not long before he boldly struck out for himself as a builder of machinery, becoming the pioneer in this country in the business of making tools for the working of sheet metals. Mr. Bliss attended to the details of his business with unyielding persistence, keeping his aim high as to the quality of the work turned out; the integrity of his word; the paying of bills exactly when they were due, and seeing to it that his men received their pay at the end of each week, without exception, during all the thirty-five years that he has been in business.

It was up-hill work at first. His means were very limited; he had no one upon whom he could call for help, and while sometimes discouraged and on the point of giving up, he nevertheless struggled on, achieving final victory in building up the two great plants over which he presides to-day,—The E. W. Bliss Company and the United States Projectile Company, employing together over 1300 skilled workmen.

One of the secrets of his success has, undoubtedly, been the inborn faculty of selecting the proper men to assume responsibilities and carry out his ideas of how the business should be carried on. He always cared more for pleasing a customer than for taking his money. Absolute truthfulness and reliability have been with him a hobby. He demands these qualities in his trusted men and has very rarely been disappointed in those upon whom his choice fell.

A BURRO BAGGAGE TRAIN LOADED WITH CAMERON PUMPS

PUMPING MACHINERY FOR MINE SERVICE

THE proper drainage of a mine has always been a knotty question, and only the last few decades can show distinct progress towards a really practical solution of the problem. The early engines were exclusively overground ones, with rods hung down the shaft, working pumps situated at different levels. Each of these passed the water on to the one above besides dealing with that collected on its own level. These engines were of the beam type, without fly-wheels, and constituted the first adaptation of steam as a motive power. It was on them that Newcomen, Watt, Trevithick, and Stephenson made their experiments and most important inventions. In a modified form, known as the Cornish engine, they attained fame and general use; in fact, for a long time they were the accepted standard for pumping engines, and to this day there are not a few of them either in actual use or standing in reserve.

Electrically-driven pumps would seem to offer a good substitute for ancient methods of unwatering mines, but they are extremely expensive in first cost and maintenance as well, and present problems that have not, as yet, been fully overcome in practice. Therefore, for the present at least, and until electricity can be harnessed and controlled and adapted to mining work at the minimum expense, it is necessary that a thoroughly reliable mine pump should work equally well with compressed air as with steam, for the use of air is much to be preferred to that of steam. Among the few good pumps that can be safely recommended as being thoroughly reliable and effective when operated either by steam or air, the "Cameron" is generally conceded to be the best, and holds the leading position.

It is a very general, though mistaken, idea that the question of steam economy in an engine working down a coal mine is not of importance. One should not lose sight of the fact that a high consumption means more boiler power required, larger pipes and increased cost of insulation, besides the inconvenience of a higher temperature in the mine and of warmer water due to greater quantity of steam condensed. It cannot, therefore, be considered true economy to put down cheap and uneconomical machinery, as any saving on this count is soon eaten up by the enhanced cost of the accessories and fittings.

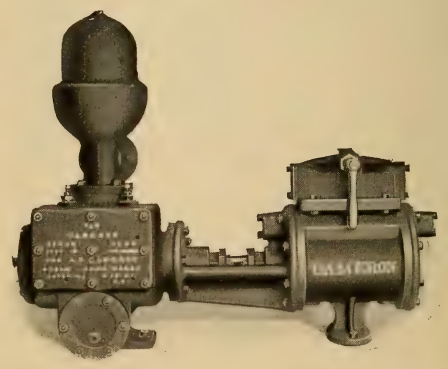
This article has been prepared with particular reference to the genuine Cameron pump, manufactured by the Cameron Steam Pump Works, whose trade-mark is better known probably than any other trade-mark in the world.

A trade-mark to be representative should be the synonym of what it stands for, and carry with it an apt illustration and clear expression of the idea sought to be conveyed. In the choice of an

THE CAMERON TRADE-MARK

acorn for a symbol and the adoption of its shape in the design and construction of the air vessel for their pump, the Cameron Steam Pump Works long ago made a most fitting selection. For as the acorn typifies the strong and sturdy oak, without a peer among its fellows of the forest, so the "Cameron" has stood for nearly half a century unparalleled among its rivals for simplicity yet superiority of design, compactness and strength of construction, certainty of operation and reliability in long-continued service. "No pent-up Utica confines its powers" nor its selection, for while its name is like a household word among users in our own country, its fame has penetrated everywhere; and to-day it is in liberal use in the mines of Canada and Mexico, Central and South America, under the nodding pines of Norway, beyond the Caucasus and steppes of Russia, in the mines of Siberia, the oil fields of Baku, and throughout Middle Europe; among the coal mines of Germany, in the larger manufacturing cities of La Belle France, in Austria, Spain, and even in the "Tight Little Isle" itself, where it long since served as a prototype for others. In the Orient, as well as in the Occident, it has won an enviable fame and reputation, and "Oom Paul's" erstwhile compatriots join with our antipodean neighbors in Australia in singing its praises.

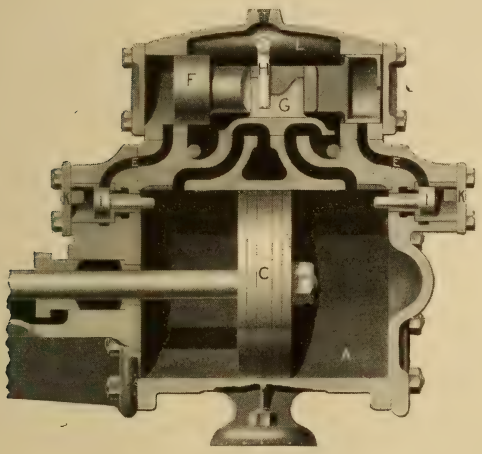
Seriously speaking, it is well and favorably known all round the world, and paraphrasing Puck, it puts a girdle round the globe in more than forty cities. The secret of its success is the sense of security it gives to its patrons and users, and its reliability under the most trying and exacting conditions, which is attributable to the merit of its design and the care of its construction. It has few working parts and none exposed to external damage, and yet careful and just consideration has been given to minimizing the necessity for and the cost of repairs, so that a part when worn out can be renewed cheaply and not involve the purchase of well nigh an entire pump; as would be the case with many other makes, and particularly those of the Duplex type, where almost the whole pump is cast in one piece. Many intending purchasers of steam pumps are influenced by the glamour of low initial cost, losing sight of the established truth that the best in everything is always the cheapest, and in nothing does this apply with greater force than in the selection of a steam pump. A



brief explanation of the steam end and water end of this pump may prove interesting, and we quote from their own statement and refer to the accompanying illustrations.

"THE CAMERON STEAM END"

All single, direct-acting pumps make use of an auxiliary plunger to carry the main slide valve, which gives steam to the main piston. By means of various



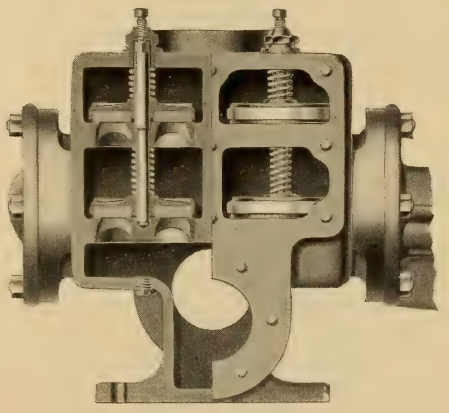
devices steam pressure is made to drive this auxiliary plunger backward and forward. In the "Cameron" pump the plunger is reversed by means of two tappet valves, and the entire mechanism thus consists of four stout pieces only, all working in direct line with the main piston. Simple and without delicate parts, it is the only inside valve gear that is absolutely reliable.

Of the water end, the valve chest is the most important part, and we quote from their description as follows:

"THE CAMERON WATER VALVE CHEST"

The illustration shows the "Cameron" valve chest and arrangement of valves. The right-hand side is shown in full as it appears when the bonnet is removed and the left-hand side in section. The superiority of this valve chest lies in its accessibility. By simply removing one bonnet or cover the whole interior with every valve is plainly visible, turned inside out, so to speak, and not a speck of anything that may have lodged there can escape detection. The shelves or decks are bored out tapering, and the brass seats forced in. They can thus be readily taken out and renewed at any time. Each stem holds two valves, with their springs one above the other, so that by simply unscrewing one plug and pulling up the stem both are released. It will be noticed that the "Cameron" valve chest is placed close to the ground and beside the water piston, instead of above it, as in other makes. The valves are, therefore, so much nearer the water, and the suction lift is reduced accordingly. Every pump has two suction openings, one on each side, and the discharge opening can be turned in any direction desired.

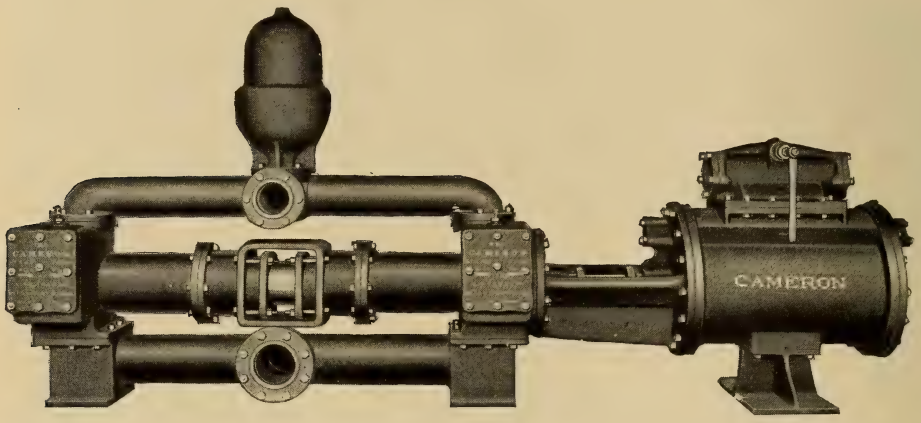
Our space permits but a brief mention of a few of the types of the "Cameron" pumps, and first place should be given to that which they designate as their "Regular" pump, as shown in the illustration on opposite page. This was the original invention of Mr. Adam Scott Cameron over forty years ago, and was first designed for use in the United States Navy and the merchant marine, to take the place of the cumbersome and expensive crank and fly-wheel pumps then in use. Later it was used in the oil fields of Pennsylvania for pumping the crude petroleum from the wells to the tanks



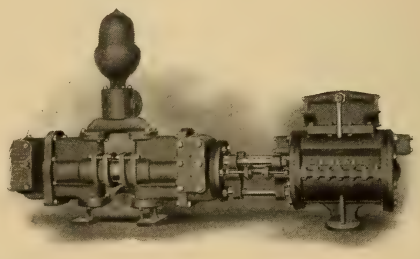
and in pipe-line operation, and was, we understand, the first pump to be used in that service; since then it has been liberally adopted for boiler feeding and general service with entire satisfaction.

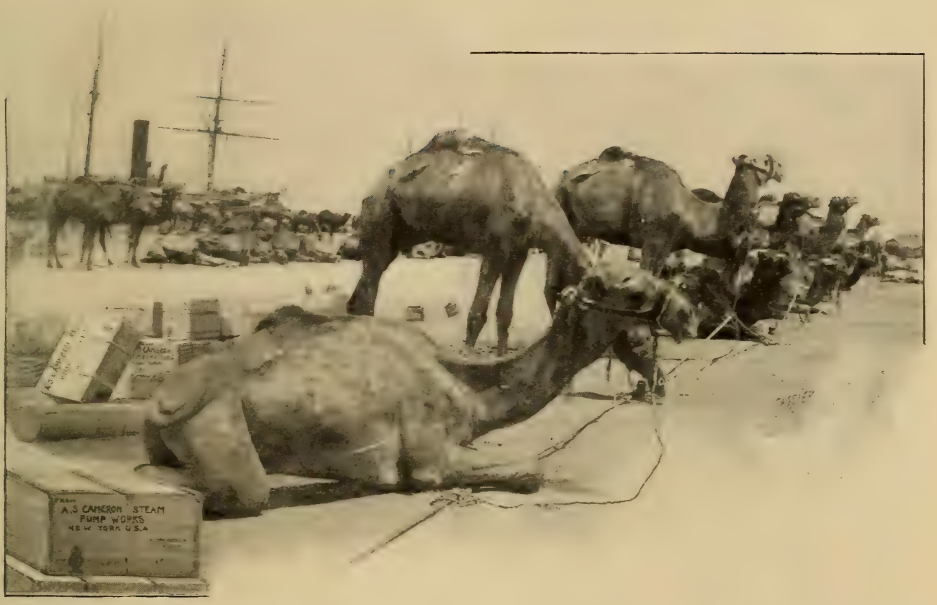
The especial use in which the " Cameron " stands pre-eminent and without an equal is that of a mine pump, and in this field its peculiar merits find best expression and its superiority is fully and clearly demonstrated. While they build many designs for both " Station " and " Sinking " service, we can refer to but a few, and first we would call attention to their " Pipe Pattern Outside Packed Plunger Mining Pump." All that we have said of their pumps as to their simplicity, durability and absence of outside valve gear gains double force when mining work is considered. The accompanying illustration shows the pump referred to, which the writer believes to be the best yet designed for working under the most severe conditions and where the water contains sand or grit or is strongly impregnated with acids. In this connection it is unnecessary to say that no iron can definitely resist the worst kind of acid water. But solid composition water ends in pumps of large capacity are very costly, and this pump is practically built in sections, so that if any part is finally eaten away it can be replaced at a minimum of expense, and the whole water end is not ruined. The latest patterns embody all the improvements that years of experience in mining work have suggested. There are no rods, arms or working parts exposed to rust or damage either from carelessness or accident. The plunger, being supported in packing boxes near the centre, cannot sag or get out of line at the ends of the stroke. Although the pump is so compact, all parts are readily and easily accessible, while the water end is made exceptionally heavy and with large valve area.

Another type of " Station " pump is their " Mountain " pattern, which is their " Regular " horizontal outside



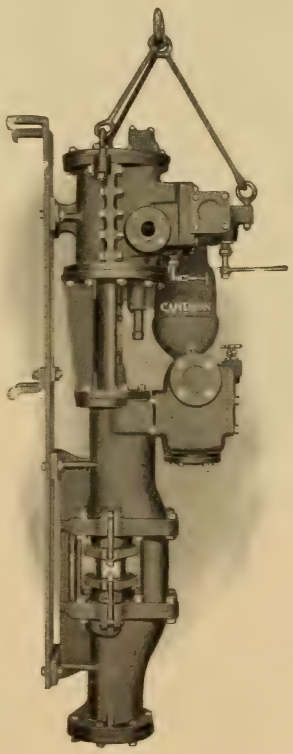
packed plunger pump built in sections for mule-back transportation. It is designed for regions where transportation facilities are crude and the maximum unit of weight is limited to 300 pounds. In many of the sizes not more than two pieces reach the maximum weight, the other parts being within 150 pounds each; it also represents an admirable type for use in bad mine water, where the capacity required is less than that of the smallest size pipe pattern pump.



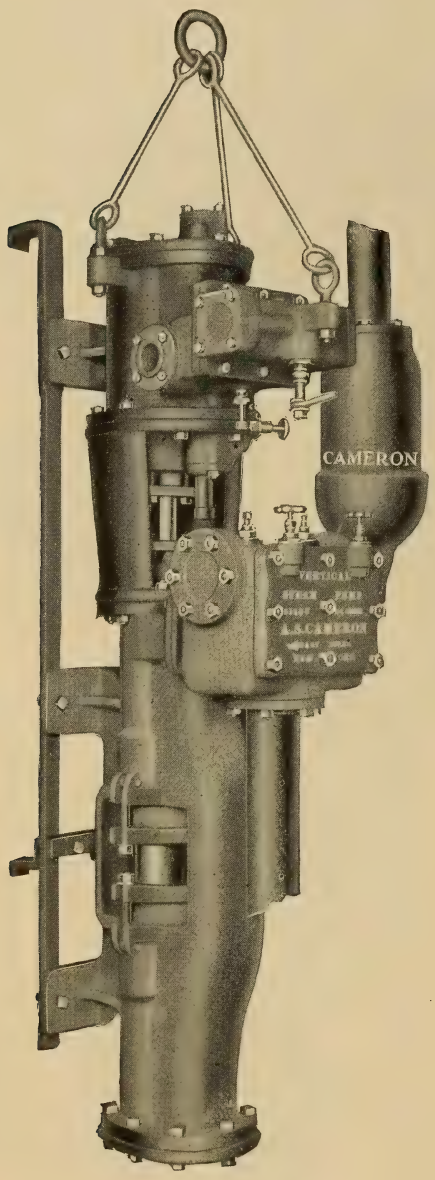


CAMERON PUMPS IN THE FAR EAST

The "Sinking" pump is also sectionalized, as shown in the illustration, and is their "Regular Vertical Plunger" pump built in sections, and is known as their "Sierras" pattern, which, with their "Mountain" pattern, has found its way on mule-back, and even more primitive modes of transportation, over the mountain passes and terraced ranges of our country and Old Mexico, Colombia, Peru, Chili, and other mining regions in Central and South America. Reference to their sectionalized sinking pump brings us naturally to a consideration of their famous and justly celebrated "Regular Vertical Plunger Sinking" pump. It is conceded by users generally that this is the best designed and constructed and most successful sinking pump on the market to-day, if we accept the postulate that any steam pump used in sinking a mine shaft must be of simple yet superior design, strongly built, certain in operation, capable of handling gritty water, require little attention, and, above all, to stand the roughest kind of treatment.



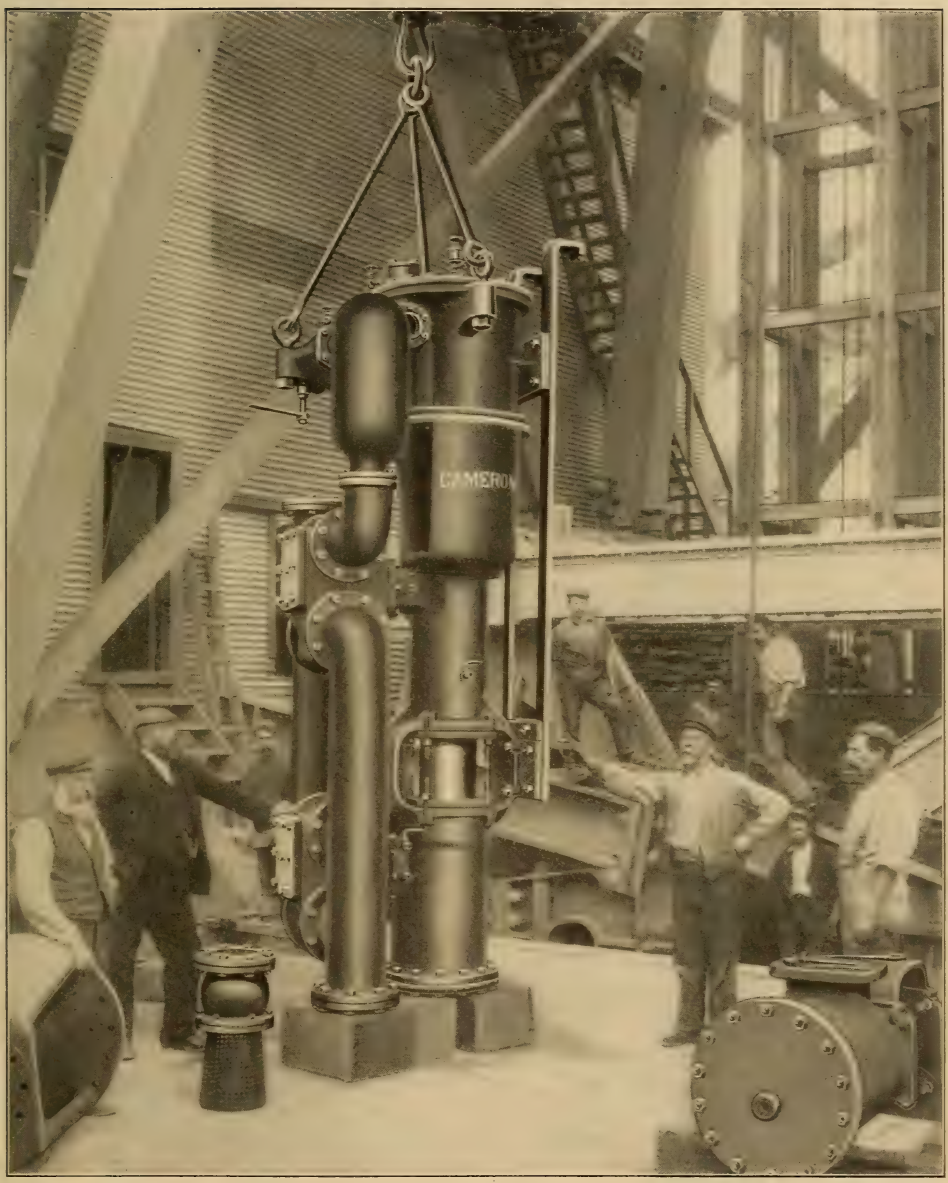
That the "Cameron" meets these conditions fully is attested by its universal selection; it has no outside valve gear, arms



or levers to be bent or broken off, and consequently suffers little damage from collision with the walls of the mine shaft, and is less likely than any other make to be injured from the explosion of blasts; its exhaust cut-off permits it to be operated as fast as steam will drive it, with an irregular or intermittent supply of water, or even when the water fails entirely, without danger of the piston striking the heads and with little injury to the valves. Unlike other inside valve movements, the "Cameron" steam end is not delicate nor complicated; but, being simple and reliable, it is vastly superior for service in a mine where the attention of a skilled engineer is seldom available. It takes up less room in the shaft than any other sinking pump, and will work in any position. It is packed from the outside easily and quickly, the glands being supplied with hinged bolts. There are no parts exposed to rust, and in numerous instances of record it has started and cleared a shaft of water when it has been buried for weeks under a fallen mass of rock and debris.

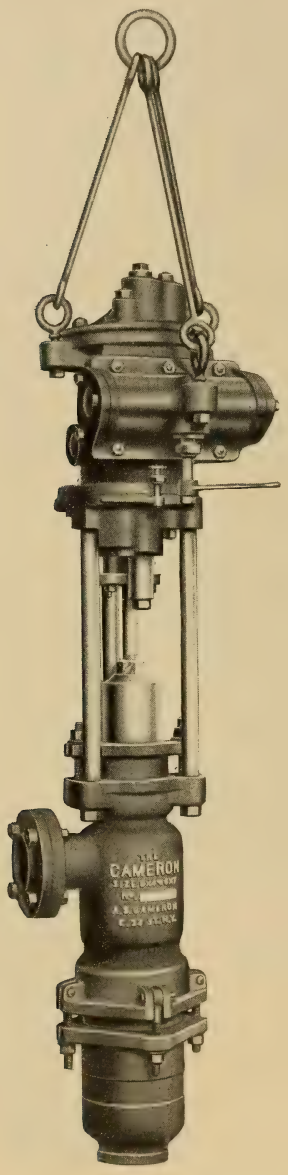
Attention is invited to their recently patented priming device with which they equip all their sinking pumps. The priming valve used on other makes of pumps is open to at least two objections; by its operation the whole weight of water in the discharge column is precipitated into the suction hose, which being designed to resist collapse only, is sometimes ruptured by the undue strain. Furthermore, any accumulation of dirt behind the valve is likely to render it locked and immovable. The "Cameron" priming valves entirely remove these objections, and, at the same time, do not project laterally, and cannot be injured or snapped off by blasting or collision with the wall of the shaft, thus leaving the "Cameron," as before, the only sinking pump that is absolutely invulnerable and safe from external injury.

It is said that "imitation is the sincerest flattery," and if this be true the "Cameron" has the endorsement of those rival manufacturers who have built a sinking pump more or less similar in appearance and advertised and offered as "Cameron pattern" pumps. When you consider the possible conse-



CAMERON VERTICAL PLUNGER SINKING PUMPS. CAPACITY 1,500,000 GALLONS PER DAY, BEING PLACED IN THE MINES OF THAMES HAURAKI GOLD FIELDS, LTD., NEW ZEALAND.
SOLD BY JOHN BURNS & CO., AUCKLAND, N. Z.

quence of having a pump break down at a critical time and the mine drowned out, you will undoubtedly recognize the



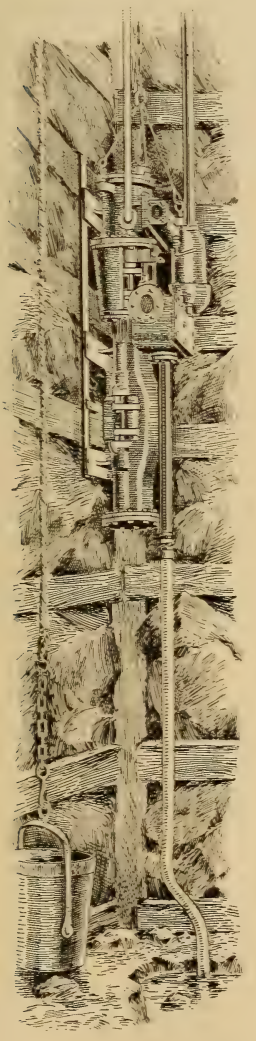
advisability of giving the preference to the genuine rather than to the imitation, presuming always you concede that the type and design are the best for the work.

In addition to the "Regular" sinking pump and the "Sectionalized" sinking pump, they build a small size sinker, which they designate as their "Prospectors" sinking pump. This pump is of their "Regular" pattern, but designed to meet the requirements of those who need a small sinking pump while prospecting, or in any situation where a pump of large capacity is not necessary. They have also recently designed and built for use in the rapid transit tunnel work now being carried on in New York city a new type of light service sinking pump, which they designate as "The 'Contractors' Differential Plunger Pump."

This pump was originally designed for a light-weight machine discharging considerable water to a limited elevation, and one requirement was that it should be able to handle water mixed with considerable sand. For this work it is particularly well adapted, as the water flows in a steady current in *one* direction, and is not retarded by its passage through the valves, which have ample and large interstices. These qualities also permit of a comparatively high speed, and the discharge of a large quantity of water relatively to the size of the pump. Minimum weight was one of the chief requirements in the situation for which this pump was designed, and this is obtained by discarding the valve chest and air vessel, which are not required, as the valves are in the lower cylinder and plunger and the upper part of the plunger performs the function of an air vessel.

The construction of the water end is simple, and the illustration renders an exhaustive explanation unnecessary, and the operation will be easily understood. On the up-stroke there is forced from the lower chamber one-half the quantity of water drawn in, the remainder being discharged on the down-stroke; thus, on the up-stroke a certain quantity, equal to one-half of that drawn into the cylinder, is discharged, and on the down-stroke the other half is forced into the discharge column; but the flow is in

one direction, whichever way the plungers move. The latter fact prevents the accumulation of sand on the valves, and avoids the trouble which is inevitable with a pump having a valve chamber in which the construction admits of the



settling of the sand and its accumulation over the valves. Although designed to meet special requirements of tunnel work, for which it has proved to be admirably suited, it can be used for higher lifts, as there is much less frictional resistance in this pump than in the ordinary sinker, owing to the undisturbed flow of the water in one direction. The lower valve is made readily accessible by allowing the lower chamber to swing on one bolt, and the others being hinged, may be easily and quickly thrown out of the slots. The upper valve seat is screwed in from the bottom on a coarse thread, and, when unscrewed, removes the valve with it; the valves are usually made in two pieces screwed together with a leather or rubber ring between, which may be renewed when necessary at very slight expense. But other valves may be provided for when desired; for instance, ball valves, but as these pumps are intended for rather high speeds the ball valves act too slowly, and the efficiency is greater with those now provided.

This pump was very favorably received and liberally employed along the tunnel, and, as its merits became better understood and fame extended, inquiries were made for pumps of the same design, but of larger capacities and for heavier lifts, and they have since developed an enlargement of the type which they call "The Differential Plunger Sinking Pump." As stated above, the small size or "Contractors" pump, originally designed for a special purpose in connection with the work on the Rapid Transit tunnel in the city of New York, gave such excellent results that it created a demand for other and larger sizes, in the designing of which they have incorporated ideas which are developments from their experience in the work for which these pumps are particularly adapted. As in the small size, the direction of the water current is always upward, whether the plungers are moving upward or downward, and to further maintain this principle the discharge elbow is cast on the pump. In the illustration a belt will be noted around the barrel, which has a downward slant, and at the lowest point is screwed a drain cock. This belt represents the outer metal of a gutter which starts at the top part of the lower stuffing box, and its function is to catch any sand which may have a tendency to gravitate

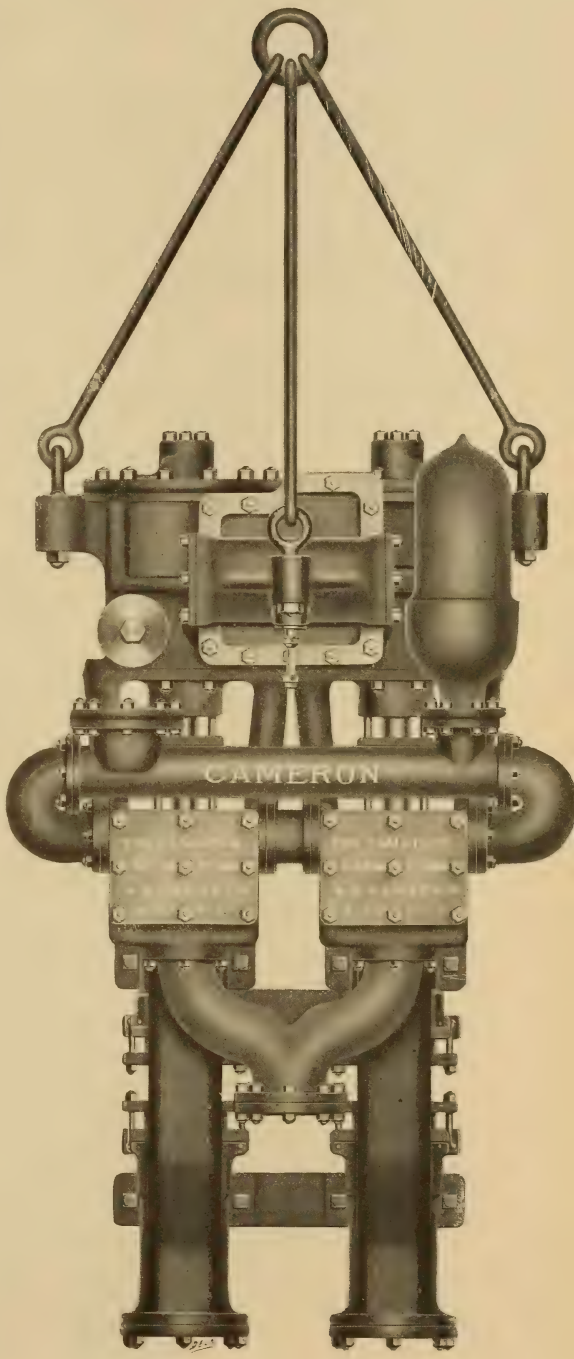
to the top of the stuffing box, and which without this provision would scour the

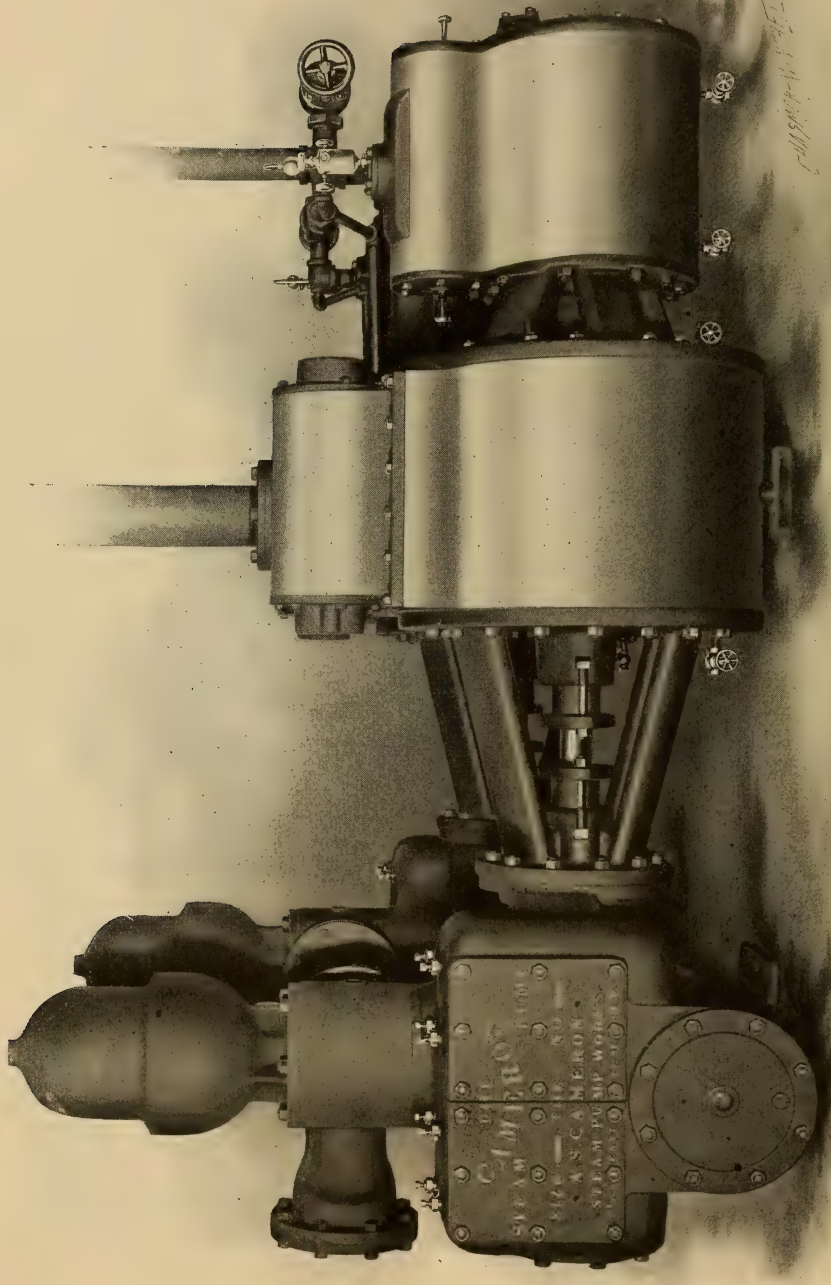
plunger. Reaching from the upper chamber of the pump down to the suction flange are two long rods. These latter are designed to sustain the suction pipe when it is desired to open up the cylinder to get at the valves. Connected to the suction flange is a pipe which is free to move through a stuffing box, thus forming a slip joint. When the lower plunger requires packing, the hinge bolts are thrown back and the lower chamber is dropped sufficiently to give room to manipulate the packing with ease; and when the lower valves require examination the chest containing them may be dropped, leaving ample room to get at them for any purpose. When the upper valves, which are in a plate hinged to the bottom of the lower plunger, require attention, they are made readily accessible by dropping the valve plate to an angle, using one or two of the bolts as hinges. The great advantages possessed by this pump, and which increase its efficiency and make it particularly well adapted for sinking mine shafts and kindred purposes, are as follows:

The use of hinged bolts on the water end and the avoidance of the occasional inconvenience of the loss of a nut. The provision above referred to, to take care of any sand which may lodge at the top of the lower plunger. The convenience of packing and the accessibility of the valves, both to adjust them and to remove anything which may have lodged on the plates. Its compactness, by reason of its not having a valve chest. The absence of an air chamber on the outside because of the top of the upper plunger acting in that capacity, and the constant unbroken flow of the current in *one* direction, with freedom from the necessity of pursuing a tortuous course, all combine to make it a very reliable, serviceable pump.

It constitutes also an admirable bilge and ballast pump for use on shipboard, and is also suitable for use as a wrecking pump, as it may be made of enormous capacity without either being very heavy or occupying much space. With a capacity of 6000 gallons per minute, for instance, it need not occupy a space exceeding 5 feet 6 inches (including discharge elbow) by 4 feet.

In addition to the types of pumps already enumerated, they have designed and built quite a number of others for use in mines, of which but a few will be described. While they do not build Duplex pumps, believing them to be expensive users of steam and generally unreliable as to service and operation, they do build pumps which they consider to be vastly superior in sinking operations and for station service; of the first may be mentioned their "Double Vertical Sinking Pumps of Plunger or Piston Type." The constantly increasing demand for sinkers of large capacity has occasioned their turning their particular attention to the matter in an endeavor to meet the requirements. They have found that single pumps when built for capacities exceeding, say, 400 gallons per minute, become very large and heavy and exceedingly long when of the plunger type, and diminishing the height of the suction lift by the distance from bottom of cylinder to suction valves of the upper end. They have, therefore, designed a "Double" pump, which consists of two steam ends joined together in such a manner that one steam chest answers for both and only one pair of reversing valves are used; these latter are on the top end, and the connecting pieces have none. A simple device has been designed and is applied to enable the user to give any amount of compression to the exhaust from the lower ends without affecting the free admission of the live steam and to prevent the pistons from striking the lower heads. The water ends differ but slightly from those of their well-known single pumps, and are made separate, as the construction provides for the renewal of one when necessary without disturbing the other. The pumps synchronize, but their reversal is simultaneous, which latter fact is of little moment in a sinking pump, and this feature enables them to produce a machine much simpler in construction and with less parts than would be otherwise necessary, and lower in weight and price than for a single pump of like capacity and power. While they have only designed them so far to be operated by steam or air, they contemplate





CAMERON COMPOUND TWIN HORIZONTAL PISTON STATION PUMP

in the near future perfecting them to be operated by electricity, and they predict for all of these pumps a splendid success where perfection in operation, reliability in service and maximum capacity per unit of power are the chief considerations. They shall be glad to give any further information required concerning them or their adaptability for any situation under consideration.

They also build "Tandem Sinking Pumps, Compound and Non-Compound, Plunger and Piston types," specially arranged to give large capacity and to go in small shafts or restricted openings. Quite recently they have designed a pump to take the place of the Duplex type for station use, which they designate as "Twin Horizontal Piston or Plunger Pumps, Compound and Non-Compound, for high-duty mine station service."

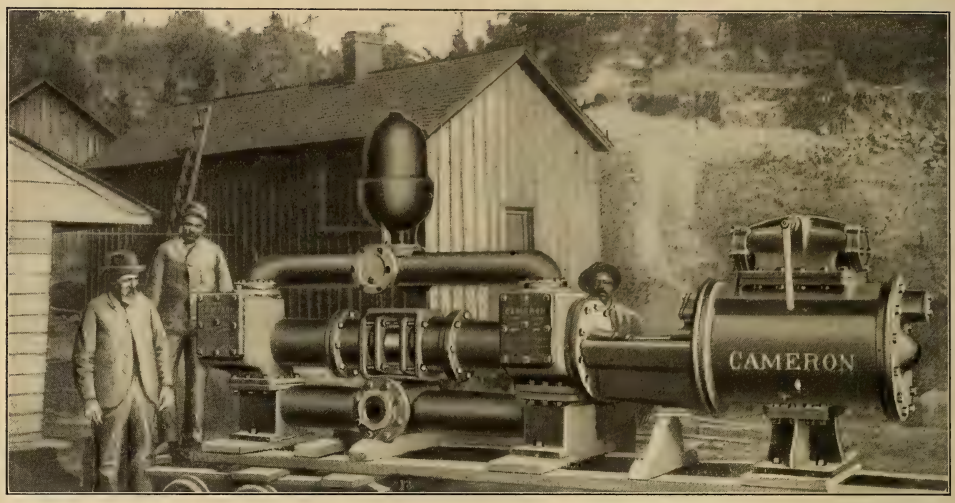
For this work they believe they can offer a pump possessing more than usual merit, having features which render it vastly superior to any ordinary Duplex pump, which are ordinarily made of one type and are very faulty in design, realizing which they have refused to go into their manufacture, although nearly all other pump builders make them. The Duplex pumps possess some theoretical advantages which are not realized in practice, and they have not hesitated to guarantee their *Single* pumps of the same proportions to do quite as much work, if not more, which they believe they are capable of doing. They have lately, however, invented a device which they term a "synchronous attachment," which, being applied to two pumps, causes them to work in harmony, and both pumps cannot reverse at the same time, but while one is passing the centre line the other is nearing the end of its stroke. Each pump can only reverse at the *end* of its stroke, which is the important feature wherein they differ from the ordinary Duplex pump, whose chief failing is its frequent short stroking, whereby its capacity is greatly diminished and the steam consumption increased (in many cases) enormously, so that they consider it the most wasteful of pumps. By their arrangement they obtain an equable flow of water in the discharge, which under heavy pressures particularly is of the greatest importance, and the economical use of steam is greatly enhanced by that fact, as well as by the well-known features of the "Cameron" pump, which tend in the same direction. Moreover, by providing suitable stop and gate valves each pump may be run separately whenever required, thus permitting the stoppage of one pump for repairs or other purposes and only partially diminishing the water supply, as the other may be speeded up.

The Compound pump also possesses characteristics which render it superior to all others in the market, as it retains the "Cameron" feature of inside valve gear, and is so simple in its design that no more skill is required to run it than a Simple pump, and it has the additional advantage of being even more positive in its action than a pump not compounded.

In the foregoing we have devoted considerable space to illustrating and describing the mining pumps built by the Cameron Steam Pump Works, believing that we were conferring a favor on mine owners as well, for it is not enough that they should have a pump that will force water from their mines—any number of pumps on the market will do that—but as good business men they will require a pump that *will* do its work, and do it with the greatest *economy* of time and maintenance and *without* detriment or failure at critical times.

A pump that is reliable in service, economical and certain in operation, of great effectiveness, and in which the amount of attention and cost of repairs and maintenance have been minimized and reduced below that of any other, is the great desideratum, and such a pump we believe the Cameron to be. It has stood the test of time and hard usage with satisfaction to users everywhere, credit to its originators, and pre-eminence as The Standard.

Their works and main offices are in New York city, where they maintain a



CAMERON PIPE PATTERN PLUNGER STATION PUMP, CAPACITY 500,000 GALLONS PER DAY, BEING PLACED IN THE MINES OF THE MONTEVALLO COAL & TRANSPORTATION CO , ALDRICH, ALABAMA. SOLD BY THE MILNER & KETTIG CO., BIRMINGHAM, ALABAMA

large plant at the foot of East Twenty-third street; but they have branch establishments in all of the prominent cities at home and abroad, where a full line of their pumps are carried in stock to supply the trade and users without unnecessary delay. Among these we may mention the following:—

List of Branch Establishments and Domestic Agents

Atlanta Supply Co., No. 29 South Forsyth St.	Atlanta, Ga.
Anaconda Copper Mining Co.	Butte, Mont.
P. Basche	Baker City, Ore.
Bourbon Copper and Brass Works, No. 618 East Front St.	Cincinnati, Ohio.
Levi Booth & Sons, No. 334 North Main St.	Los Angeles, Cal.
H. L. Bowman & Co., No. 31 South Fourth St.	Philadelphia, Pa.
Caldwell Bros., No. 1746 Pacific Ave.	Tacoma, Wash.
Chickasaw Iron Works, Second and Winchester Sts.	Memphis, Tenn.
Coeur d' Alene Hardware Co.	Wallace, Idaho.
Globe Machinery & Supply Co., No. 414 West Court Ave.	Des Moines, Iowa.
Gunther Foundry, Mach. Supply Co., No. 320 W. Commerce St.	San Antonio, Texas.
Ingersoll-Sergeant Drill Co., No. 84 Van Buren St.	Chicago, Ill.
Jenckes Machine Co.	Halifax, N. S.
Jenckes Machine Co.	Sherbrooke, Quebec.
Jenckes Machine Co.	Rossland, B. C.
Kupferle Bros. Manufacturing Co., No. 600 Second St.	St. Louis, Mo.
Marshall-Wells Hardware Co.	Duluth, Minn.
Miller Supply Co., Second Ave., Ninth and Tenth Sts.	Huntington, W. Va.
Miller Supply Co.	Bluefield, W. Va.
Mexico Mine & Smelter Supply Co.	Mexico City, Mex.
Mine & Smelter Supply Co., 17th and Blake Sts.	Denver, Colo.
Mine & Smelter Supply Co.	El Paso, Texas.
Mine & Smelter Supply Co., No. 224 West Temple St.	Salt Lake, Utah.
Milner & Kettig Co.	Birmingham, Ala.
Mitchell, Lewis & Staver Co., No. 308 First Ave., South	Seattle, Wash.

PUMPING MACHINERY FOR MINE SERVICE

New Orleans Railway & Mill Supply Co., No. 620 Camp St... New Orleans, La.
Oil Well Supply Co..... Bradford, Pa.
Oil Well Supply Co..... Oil City, Pa.
Ottumwa Iron Works, corner Main and Wapello Sts..... Ottumwa, Iowa.
Pittsburg Valve, Foundry & Cons. Co., No. 108 Third Ave..... Pittsburgh, Pa.
Prescott Supply Co..... Marinette, Wis.
M. F. Rourke & Co., No. 717 Gay St..... Knoxville, Tenn.
Roy & Titcomb, Inc..... Nogales, Ariz.
Rundle-Spence Manufacturing Co., No. 29 Wisconsin St..... Milwaukee, Wis.
Spokane Hardware Co., No. 516 Riverside Ave..... Spokane, Wash.
Union Iron Works, No. 222 Market St..... San Francisco, Cal.

Branch Establishments and Agencies in Foreign Countries

John Gillespie & Co., 1 Leadenhall St..... London, E. C., England.
Lorentzen & Wettre..... Christiania, Norway.
Tornborg & Lundberghs Eftr..... Stockholm, Sweden.
Max Brandenburg, Oranien-Strasse 141..... Berlin, Germany.
Persicaner & Co., 1 Libenberg-Strasse 7..... Vienna, Austria.
Garteiz Hermanos, Yermo y Cia..... Bilbao and Gijon, Spain.
Arnhold, Karberg & Co..... Shanghai, China.
Ingersoll-Sergeant Drill Co..... Johannesburg South Africa.
John Burns & Co., Custom St., East..... Auckland, New Zealand.
James Martin & Co., 161 Clarence St..... Sydney, N. S. W., Australia.
W. & J. Lempriere, 506 Little Collins St..... Melbourne, Australia.
W. & J. Lempriere..... Zeehan, Tasmania.
Frank R. Perrot..... Perth, Western Australia.
Frank R. Perrot..... Brisbane, Queensland.
Robert Graham, Engineer..... Ponce, Porto Rico.
Hampshire & Co., 40 Rua Visconde Inhauma..... Rio de Janeiro, Brazil.
John R. Beaver..... Valparaiso, Chili.

Represented through correspondents and the trade in general in France, Belgium, Holland, Denmark, Italy, Russia, Japan, India, Java, Philippine Islands, Sumatra.

SPEED REGULATION IN MINING OPERATIONS

FRA ELBERTUS has said: "If you have not seen the best it is quite easy to be content with something else. Aye, men have been known to wax boastful over a thing that was extremely faulty, and to declare that the pattern of the thing came from On High." This seems to be, or rather to have been, particularly true in regard to the devices used to control the speed of the prime mover, be it water or steam, used in mining operations.

In the past almost any sort of a device which would prevent too frequent runaways and keep the speed somewhere within reason was regarded as good enough. As a matter of fact, there is almost no machinery used in mining which may not be more advantageously operated at a constant speed than at a variable speed. With some mining apparatus, as, for example, dry separators and concentrators, the success of the whole process depends on the accuracy of the speed regulation. In electrical power transmission at high voltage accurate speed regulation is an absolute necessity, and even at low voltage who will say that poor speed regulation is a good thing?

In another class of mining machinery, as, for example, air compressors, it is desirable to vary the speed suddenly through wide range; but the speed, though variable, must be under perfect and instant control. To one who has not seen the best types of speed regulators at work, and watched their almost human intelligence, the cruder forms of apparatus seem good enough. Anyone, however, who has seen a Lombard water-wheel or steam engine governor at work and is aware of what the machine is actually doing, will realize the force of Fra Elbertus' remark.

The Lombard governor is now used with more than 300,000 horse-power of water-wheels alone in this country. In all of this large practice they have been guaranteed to give the best attainable speed regulation, and the makers have never yet failed to maintain the guarantee. There is no make of turbine or impulse wheel which has not been regulated by them, and there is almost no set of hydraulic conditions in which they have not been used with eminent success.

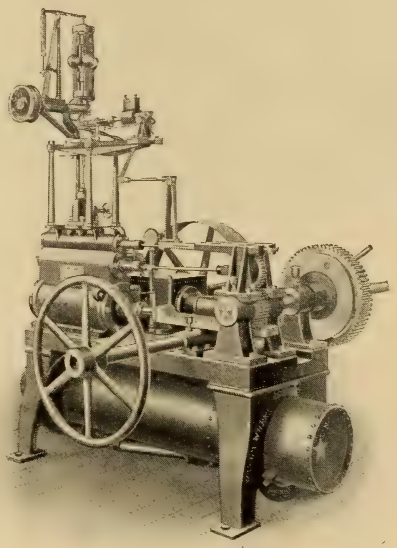
As for steam engine regulation, the Lombard governor permits of any instantaneous variation of load within the capacity of the engine without disturbing the speed sufficiently for the variation to be noticeable.

The makers have some interesting literature in regard to the performance of these governors.

If you would know more of this matter, write to The Lombard Governor Co., 36 Whittier Street (Roxbury), Boston, Mass. By stating your requirements fully and specifically, they will be able to make a more interesting reply than if your inquiry is of a general nature only.

Fra Elbertus is a sage, and, therefore, wise enough to confine his sayings to those things with which he is familiar. The engineers of The Lombard Governor Co. are weak in philosophy, but they have developed an unusual amount of knowledge about speed regulation. Fra Elbertus looks at things as through the large end of a telescope, and sees a whole landscape of facts crowded so closely together that he can establish their general relations. On the other hand, the experts of The Lombard Governor Co. have been looking at the matter of speed regulation through the microscope of daily experience, and while their field of vision has

been limited, they have seen the details and studied them until their eyesight has been made keen. They delight in studying new problems of this nature. They have found out that a lot of facts are more significant than they seem. Possibly you have overlooked some trifle which is affecting the speed regulation of your plant. It may be something which can be corrected without expense, or it may be a matter which cannot be changed at any cost. Perhaps a Lombard governor would be of no value to you. At any rate, write to The Lombard Governor Co. about your troubles, and you will get advice which will cost you nothing, and will be truthful even if incomplete. This concern does not do business on the pay-if-you-are-cured plan. If they are sure that they can help you, they will tell you what it will cost and will do as they say, even though they lose money; but they haven't been losing much money, for they know what they can do and don't attempt the impossible.



Some governors are guaranteed to maintain constant speed of water-wheels under all conditions of load and water supply. The Lombard will not do this, because it cannot push the water-wheel if the water does not flow fast enough. It will, however, move the water-wheel gates with the utmost rapidity to correspond with load changes, which is what all governors should do. A Lombard governor will move a gate weighing six tons the whole length of its travel in two seconds or less. This is because of the hydraulic relaying device. We have not heard of any other governor which can approach such speed. A Lombard governor will move a gate a tenth part of its travel and not overreach itself a particle. This is on account of its anti-racing device. We know of governors which will hunt around ten minutes trying to locate a gate in its proper position.

A Lombard governor can be made to increase or diminish the speed of a water-wheel by an electrical impulse from a distant point. Therefore it is possible to control water-wheels absolutely, even to the extent of starting and stopping them, from a central place, throughout a large power house, or even several power houses miles apart.

There are not many machines which can perform even one operation as perfectly as a human being, although they may multiply the production a thousand-fold; but for moving the gates of a water-wheel to produce the best speed regulation, no man can equal the perfection of touch and accuracy of the Lombard governor.

The Lombard Governor Company, Boston, Mass.

THE MODERN ROCK DRILL

THE steam or rock drill, as known to-day, is an American invention, and its inception dates back to the excavation of the Hoosac Tunnel, in Massachusetts, an enterprise fathered by the State of Massachusetts during its period of construction, and beset with difficulties, the recital of which would make a romance such as would astonish the engineers and tunnel operators of to-day.

To commence the excavation of a tunnel five miles long, through hard rock, and to do the drilling by hand, was in its day an audacious proposition; but that was the one undertaken by the State of Massachusetts.

In those days of inexperience, many methods of excavation were proposed and tried; machines were built, tested and condemned. One of the interesting machines made was a horizontal rotary milling machine to cut out the full size of the heading. Among the inventors, the man who schemed the machine which, in its general features, embodied the requirements of a perforator for making holes for blasting, was Mr. James W. Fowle, of Boston, who made the first machine in which the drill steel was made the extension of the piston rod of a reciprocating steam engine, which was fed toward the rock as the drilling advanced; the piston having a slow rotary, as well as a reciprocating motion, to prevent the drill from making anything but a round hole. Mr. Fowle's invention covered all of these points, and I believe that it was the first one which made the steel the extension of the piston rod. With this foundation the machine was improved in details in the shops of the Fitchburg Machine Works, by the mechanic Burleigh, and a tunnel drilling machine was made, which did effective work at the Hoosac Tunnel and expedited its completion, but without notable economy. The machines were heavy, and could only be used practically when mounted on a heavy carriage running on wheels on a track. They were too heavy for mine and quarry work, although a few of them were used.

RAND DRILLS IN DARKEST AFRICA

Later, came the demand (largely from New York City, which is built upon

a rock) for a lighter machine, and the Little Giant and Eclipse machines were found useful. The Eclipse machine was operated by a piston valve previously in use in a steam pump, and the Little Giant was operated by a positive motion valve. The rocker used was a simplification of the Burleigh, and the placing of the valve inside of the steam chest, with the third arm of the rocker projecting into it from the under side, made a short drill, which was a great desideratum for mine and quarry work.

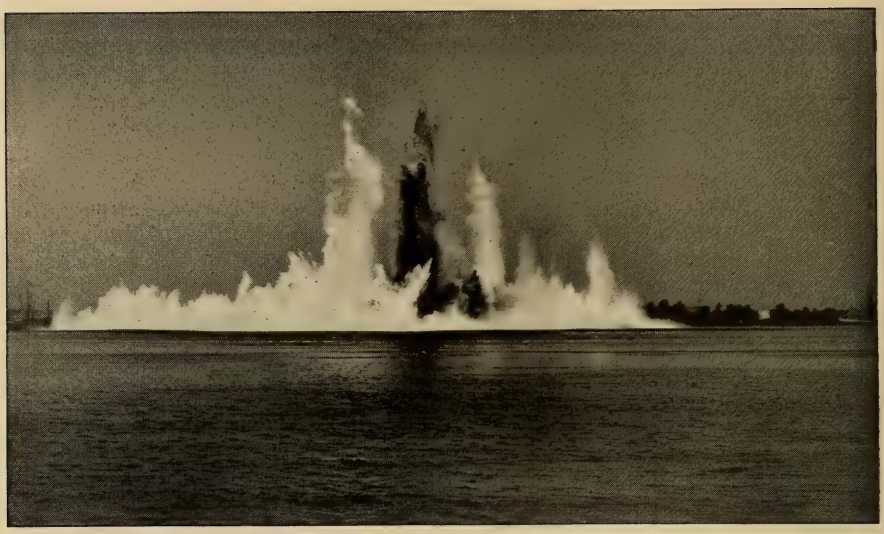
With the introduction of light drills came various improvements, which became very valuable as the scope for use of the rock drill enlarged. In fact, almost a new drill was made when the machines were applied on a large scale in New York City, for outside excavation, at the tunnel under Forty-second Street, and under Hell Gate, and also in the hard ore mines of Lake Superior.

As soon as the rock drill attained a reasonable state of perfection, its importance was immediately manifest to the world at large. It has often been called the advance agent of civilisation, and no doubt has a better claim to that

ESQUIMAUX USING RAND DRILLS

title than any other mechanical invention of recent date. All modern engineering is dependent on its use: problems which would be impracticable without this machine are rendered easy, and the results are a blessing to mankind. Its influence on mining, quarrying, railroading and navigation has been felt all over the world. From Greenland's icy mountains to Afric's heated sands, in every country, far and wide, in the mines and under the sea, this little giant is sturdily doing its work of bringing forward treasures which have been hidden for ages, and clearing the way for transportation through obstacles heretofore insurmountable. The rock drill has developed the mines of South Africa, in four years, to a production of $24,000,000 annually; and such modern engineering feats as the Hoosac and Mount St. Gothard Tunnels, Hell Gate, the Niagara Tunnel, the tunnels under Bergen Hill and the Palisades, the Croton Aqueduct and the Chicago Drainage Canal, were carried to success by rock drills. These machines, with the air-compressing plant to operate them, are now as indispensable in tunneling, mining and excavating as the air brake on railroad trains.

The effort of the introduction of rock drills for mining purposes is shown in



THE EXPLOSION OF FLOOD ROCK IN HELL GATE, NEW YORK. ILLUSTRATING THE MOST PROMINENT CASE OF SUBMARINE MINING. LITTLE GIANT DRILLS WERE SELECTED FOR THE GREATER PART OF THE WORK OF EXCAVATION IN THIS WONDERFUL UNDERTAKING AFTER COMPETITIVE TRIALS HELD UNDER THE DIRECTION OF OFFICERS OF THE ENGINEER CORPS, UNITED STATES ARMY

Rothwell's "Report on the Mining Industry" for 1892, page 137. Taking the Atlantic Mine as an example, the cost sheets of different years show the cost in 1881, the year before the introduction of drills, to have been: For stoping, per fathom, 14.35, against $4.33 for 1891; for drifting, $10.08, against $4.92 for 1891. Though it is fair to state that a portion of this reduction in cost is due to the use of high explosives.

It may be interesting to engineers, struggling with a difficult mechanical problem, to know that the comparative perfection of the machine of the present day was not accomplished without a great amount of disappointment over devices which would have worked acceptably if applied to a machine getting ordinary hard usage, but which failed utterly when applied to a rock drill. Even when the devices were wisely chosen, the question of proportions and selections of quality of steel could be decided only after repeated trial and failure, the difficulty being in the small safety factor permitted in a rock drill, on account of the light weight allowed.

The Little Giant Drill, as it stands to-day, represents a practical solution of the complex problems presented, and the files of the Patent Office will show that the present state of the art owes more to our improvements, which have proved to be lasting, than to any others.

All of the following improvements to-day in use in a rock drill, and considered essential features, were made by officers of this company, and this statement is made advisedly:—

Commencing with the cylinder of the drill, the method of using long bolts to hold the top and bottom heads in place, with an elastic buffer under a cross-head of the upper cover, whereby the blow (struck accidentally upon either head, by the piston) is absorbed, may be placed first.

The method of gripping the steel in the chuck, by means of the "U" bolt and chuck key, stands second; and no other method has been found which operators will consent to use.

The device of flanged and rotating bar dropped through the ratchet and box

was, at the time of its invention, a very great advance in the art, and it has been followed by imitators of late.

The use of the tapered throttle was also a very neat device for preventing leakage and providing a graduated admission of steam and air.

Passing from the cylinder to its mounting, the most important achievement was in the very simple device of mounting the drill on a horizontal arm attached to a vertical column, which, in turn, was mounted on a block and jacked to place by two screws, one at either end of the block. If the significance of this improvement, first used by the Rand Drill Company, had been properly appreciated at the time of its invention, a practical monopoly of the mining business would have been effected.

A kindred invention, but of less importance, was the universal joint applied to the legs of a tripod, which was first made successful by this company.

Following the above inventions come those relating to the distribution of steam or air in a rock drill, whereby the blow struck by the drill is an unobstructed one; and, as the patents will show, this company was first in the field in this respect.

The Chicago Drainage Canal, now nearing completion, affords the most recent example of the importance of power-driven rock drills in the successful undertaking of a large public work.

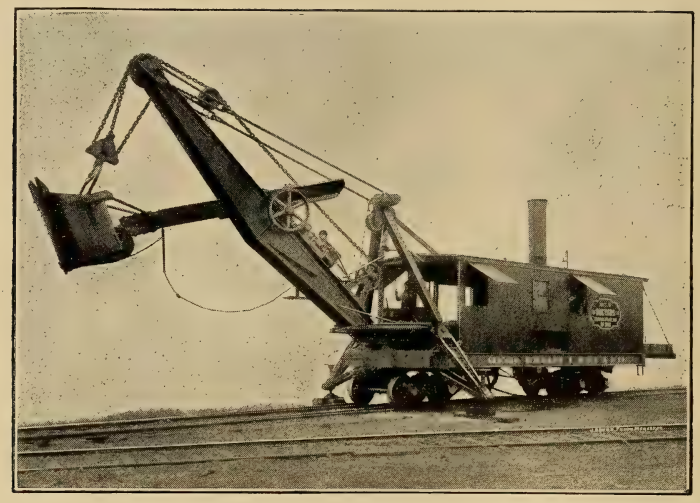
It is safe to assume that an undertaking of this character, involving the excavation of 14 miles of solid rock, 160 feet wide and 35 feet deep, or 14,000,000 cubic yards, would not have been a feasible proposition without the use of the modern rock drill. The cost of removing so large a quantity of rock by any other method would have been so great that this undertaking would never have been considered, seriously.

Here, too, our Little Giant took the most prominent part; as it has done in almost every large work requiring the use of rock drills, and where competitive trials or tests (usually conducted by competent men in the employ of the contractors) have been made; the object of such tests being to determine the class or make of machine best adapted to the work in hand, and to be used throughout the life of the contract.

THE RAND DRILL COMPANY,
New York, U. S. A.

THE USE OF STEAM SHOVELS IN IRON ORE

ABOUT ten years ago steam shovels began to be introduced in the hematite ore mines of Lake Superior, first for stripping above the ore deposits, and afterwards for loading from the stock piles. Finally, certain enterprising miners began to work the ore deposits themselves with steam shovels, the buckets being re-enforced by steel teeth, of sufficient hardness to penetrate the material. It soon became evident that better designed, more powerful and more durable



STEAM SHOVEL MANUFACTURED BY THE BUCYRUS COMPANY, SOUTH MILWAUKEE, WIS.

machinery must be employed in shovels which were to be used for this exacting service; and, as a result, the all-steel Bucyrus shovels of the boom type were brought out, and soon commended themselves to the mine owners of the Lake Superior region. These shovels were rapidly developed by the builders, and are now extensively used, not only by the hematite companies, but also for handling hard ore in stockpiles.

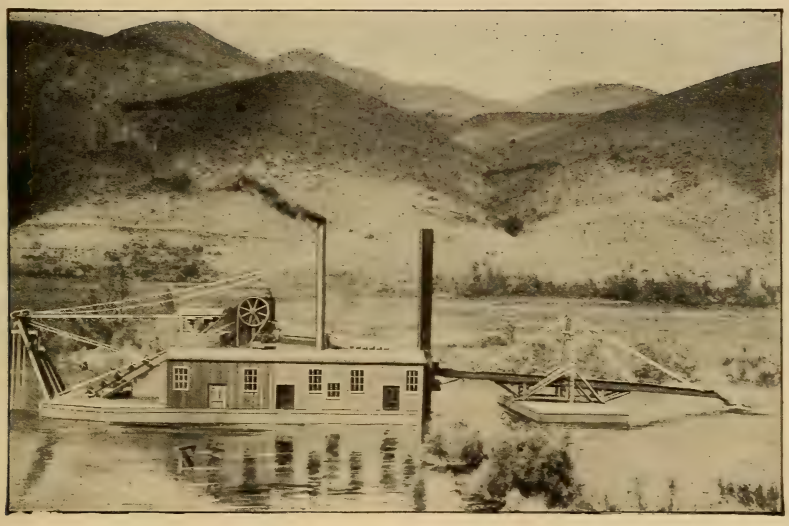
Among the companies which are using the heavy shovels of this make are:

Mahoning Ore Co.
Lake Superior Consolidated Iron Mines.
Oliver Iron Mining Co.
Cleveland Cliffs Iron Co.
Florence River Iron Co.
Newport Mining Co.
Chapin Mining Co.
Biwabik Iron Mining Co.
Iron Cliffs Co.
Penobscot Mining Co.
Penn Iron Mining Co.
Lake Superior Iron Co.
Minnesota Iron Co.
Loretto Iron Co.
Regent Iron Co.
Republic Iron & Steel Co.

THE BUCYRUS COMPANY.

DREDGING FOR PLACER GOLD

AS a result of the great stimulation which the business of gold mining has received during the past few years, the use of dredges in placer deposits, and especially for working the beds of placer rivers, has become general throughout the West, especially in Montana and California. Many experiments were made with dredges of the dipper type, and also with hydraulic dredges; but experience eventually proved that the dredge best adapted to this purpose was the dredge of the elevator or chain bucket type. Such dredges, of light construction and small capacity, were first used in New Zealand, and have since been introduced into the United States. The New Zealand machine was soon shown to be too light to treat the heavy material which abounds in most of the placers of the Western States. It remained for The Bucyrus Company, of South Milwaukee, Wisconsin, to improve and adapt this dredge to the more exacting and more difficult conditions here presented. This company has now been building placer dredges for over ten years, and has successfully adapted them to the conditions which are ordinarily presented in the free gold placers of the West.



Briefly stated, placer mining dredges may be said to consist of the following elements:

1st. Excavating apparatus to excavate the material and deliver it into a hopper;

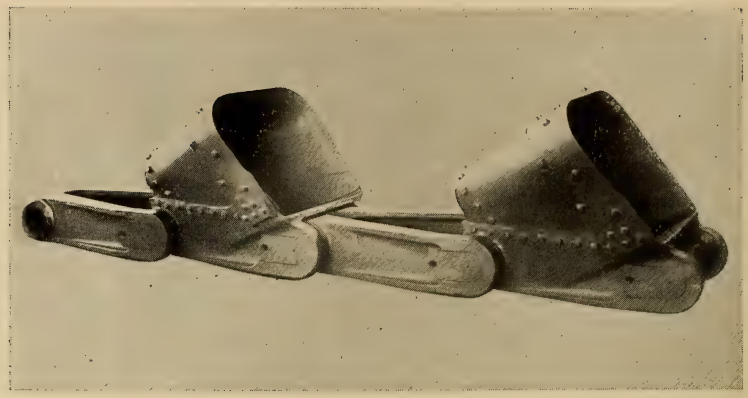
2d. A screen to receive and wash the excavated material;

3d. An appliance for carrying off the coarse tailings and the stones which are rejected by the screen;

4th. Pumps to supply water for washing and sluicing;

5th. A sluice box in which the water and fine material, containing the gold, are treated, and in which the gold is saved; or, if the gold is too fine to be efficiently saved in an ordinary sluice box, a finer screen and gold-saving tables of adequate capacity are employed. The gold-saving apparatus in every case must be specially adapted to the character of the ground.

These elements are combined by the Bucyrus Company in a complete and practical form on one hull. Those familiar with placer mining operations will at once perceive that there is here presented a simple and practical sluicing and washing arrangement, combined with powerful excavating machinery and other devices, whereby it is possible to work economically almost any placer deposit



PATENT BUCKETS WITH DIRT PROTECTED BEARINGS

where sufficient water to operate the dredge is available. There are numberless good claims lying undeveloped for want of such machines as these.

Machines of this kind, to be successful, must first embody powerful, durable, and efficient dredging and elevating apparatus. The design and construction of dredging and excavating machinery is a specialty in itself. To this business The Bucyrus Company has devoted its attention for many years.

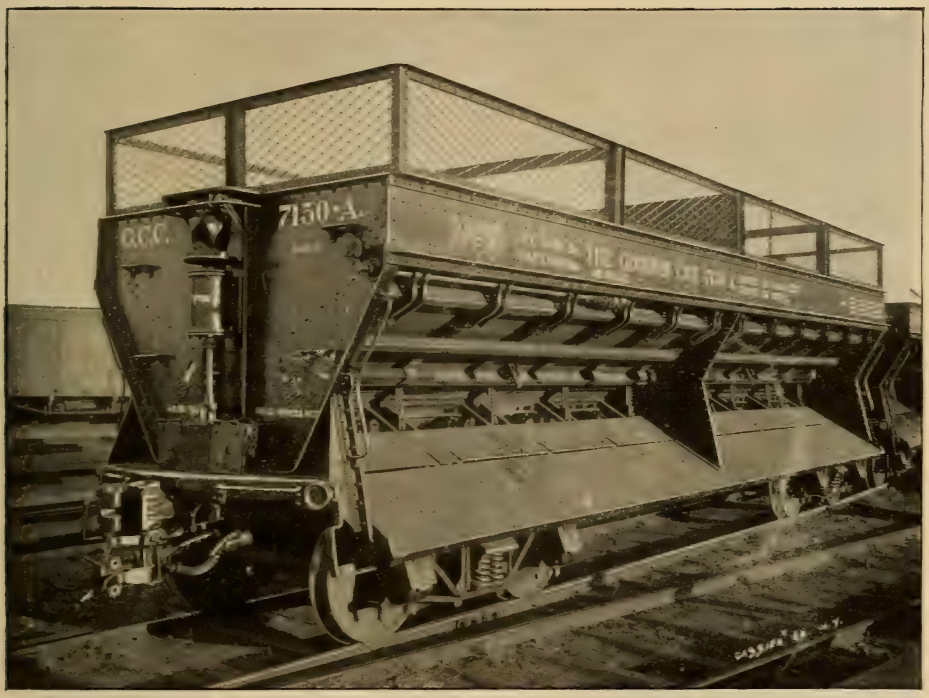
The action of the endless-chain bucket dredge is such that the material is taken up with the smallest amount of agitation, and in a manner best calculated to retain the gold. The buckets are water-tight and hold their entire contents until emptied by reversion at the top. The delivery of the material is continuous, and at the centre of the boat, instead of being intermittent and at a distance, over the side of the boat, as in the dipper dredge. The elevator buckets also bring up a considerable amount of water, which facilitates the washing operation; and the material is brought up in small masses and, hence, is more easily disintegrated in the screen. From actual results obtained by Bucyrus machines now in successful operation, it has been found that the cost of operation of such a dredge is from 3 cents to 6 cents per cubic yard. These figures are based on a season's operation, and include repairs and all other incidental expenses. The cost per yard varies somewhat with the cost of fuel and labor; but, in most of the cases where these records were obtained, these items were high. It is fair to presume that the average cost of mining by this method may safely be placed at 4 cents per cubic yard. From this it will be seen that there are many so called "low-grade" deposits which can be worked profitably. There are also many deposits of the "flat" character,—that is to say, with no "grade" at all,—which can be worked where there is sufficient water in which to float the dredge.

It is of primary importance in undertaking an enterprise of this kind to prospect the ground thoroughly in order to ascertain the value per cubic yard, and also to determine the average character of the material, the depth to bed rock, the character of the bed rock and the amount of water available. It is also necessary to know the kind and cost of fuel and the cost of labor. These are all-important factors and should be fully determined before the machinery can be prescribed.

Among the mining companies now operating dredges of the Bucyrus Company's make are the following

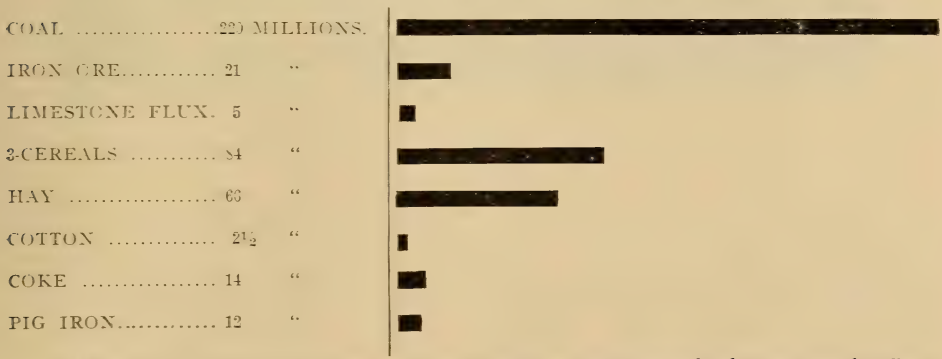
Ashburton Mining Co.; Oro Dredging Co.; Pacific Dredging Co.; The Pomeroy Co.; Horse Prairie Dredging Co.; Indiana Gold Dredging & Mining Co.; Bannack Dredging Co.; Boston & Colombia Gold Dredging Co.; Montana Gold Dredging Co.; Boston & Oroville Gold Mining Co.; Chicago Mining & Development Co.

MODERN COAL HANDLING



THE biggest business in the United States is the carriage of freight. The people of this country pay the railroads annually nearly a billion of dollars, —$1,000,000,000,—for this service. This is three times the amount paid for the carriage of passengers. Of this stupendous freight bill the principal item is to be credited to coal. If we set out the principal staple productions of the country in graphical form, their amounts bear the following proportions:—

PRODUCTS OF THE UNITED STATES IN 1898, RECKONED IN METRIC TONS (2204.6 lbs.)



With these facts in mind, it is not hard to understand why so much effort has been expended in the production of devices for the economical handling of

coal in transportation. Where so many millions of tons are annually loaded, carried, and discharged the saving of even a fraction of a cent upon each ton in any one of these operations amounts to a very large item. A tenth of a cent saved on each ton of the product of 1899 would mean a gain of $250,000 to somebody.

All coal has to be carried in cars from the mines to the point where it is consumed. It is not so hard to get the coal into the cars,—the problem is how to get it out at the place of delivery, with the minimum expenditure of time and labor,—or, in a word, of money. The solutions offered of this important problem have been many. There are hopper cars without number, among the latest being the steel hopper car; but these all have the insuperable defect of forcing the coal to an opening much smaller in dimension than the body of the load, so that the material tends to converge and pack itself, and will not flow without prodding; and the prodding takes time and labor, besides breaking the coal and so lessening its value. The writer has seen eight men occupied ten minutes in discharging a load of ordinary run-of-mine coal from a steel hopper car under the most favourable circumstances of weather,—an average record, he was told. This means eighty minutes of labor for each car discharged.

A very different mode of discharge has been applied at some of the wharves along the Great Lakes, by means of which both time and labor are saved. Incredible as it sounds to the uninitiated, they there prefer to use an ordinary plat-

FIG. 2.—TRAIN OF GOODWIN CARS DISCHARGED BY ONE MAN BY USE OF COMPRESSED AIR

form car with sides, and, by lifting car after car separately into the air, turn the coal out from it as a grocer turns out sugar from a scoop. By this characteristically masterful Western method, coal shippers at lake ports have succeeded in reducing the labor-time for each car discharged to thirty-five minutes, in some cases, and still less in others. The saving in cost over the old method of bucket, hoist, horse, and boy is said to be 90 per cent.

As the purpose of this article is to bring into view the merits of the Goodwin ar as a coal-handler by comparing its operations with the best present methods,

it will be necessary to give a brief account of the different car dumping machines to which allusion has been made.

The design and form of the Goodwin car are shown in the illustrations accompanying this article and in the advertising pages of this magazine. We will only add here that the discharging apparatus is worked in connection with the air brake system of the train (as well as by hand), and that any number of cars may be so discharged by a single operation.

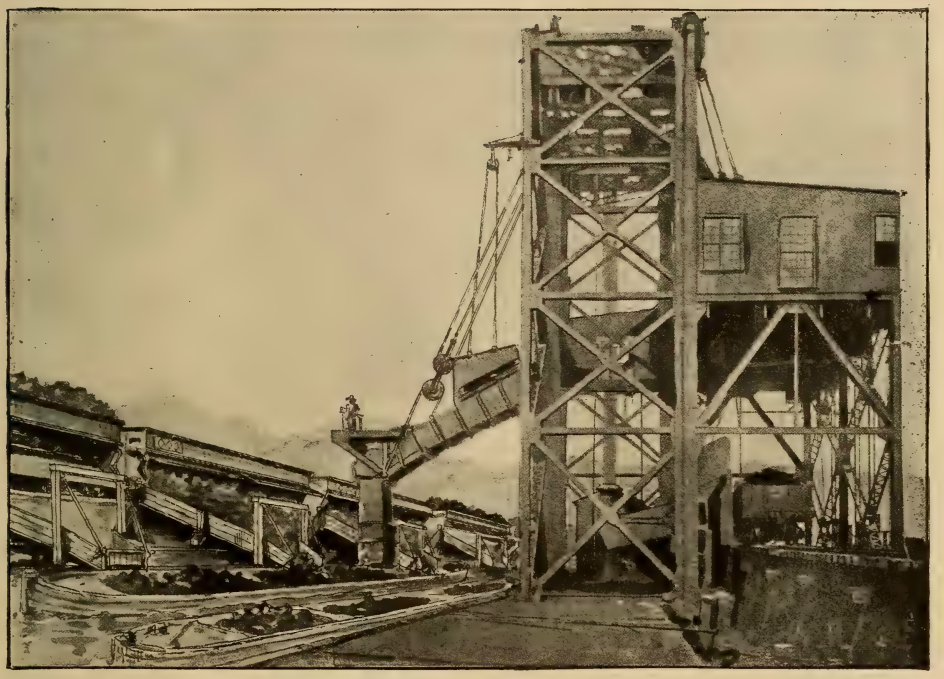


FIG. 3.—SKETCH COMPARING COMPLICATED CAR TIPPING PLANT WITH SIMPLE TRESTLE AND CHUTES REQUIRED FOR GOODWIN CARS

NOTE.—Goodwin cars are dumped in train without uncoupling

In the *Railway Era* of May and June, 1899, and referred to more recently and explicitly in CASSIER'S MAGAZINE for September, 1900, are articles describing various machines employed on the Great Lakes for transferring coal from car to vessel. Six different machines are described, all of which operate to lift the car up and turn the coal out. The first consists of a long steel tilt, resting upon a movable car base, and controlled by machinery in direct connection with it. This tilt extends from the car yards towards the water. Upon the shore end of this tilt a car is drawn up by a rope from the machine until the pivotal point is passed, when the car depresses the outer end of the tilt and assumes a position which causes its load to slide out of the end of the car into chutes leading to the vessel's hatches.

In the second, the loaded car is run upon a cradle which is lifted up and then turned sidewise, so that the coal escapes through chutes into great buckets rigged with travelling gear, which, in turn, are made to discharge into the hatches of the boat. The third device is similar in principle to the above, though differing in details.

In the fourth, the car is run into a sort of great barrel, " which is caused to

roll up an incline to a point above a great ' pan ' into which the contents of the car are dumped, and from whence, by spouts, they find their way by gravity to the vessel's hatchways."

The fifth and last instance in the May number shows a construction where " the car is picked up, elevated above a great pan, into which the contents are dumped and from which they are spouted to the vessel's hold."

The June article described what is said to be " one of the most perfectly and quickly acting coal and ore dumpers to be found in the country." In order to give the reader a right idea of the number and complexity of the operations of these machines, we will quote the description *verbatim*. " A train of coal is run into a siding having a slight gradient. The first car is uncoupled and moves slowly down to a point over a ' puller,' which hauls it up to the proper point. By the simple movement of a lever both the car and ' pan ' (a part of the machine) are now caused to tilt over, one towards the other, the coal sliding out into the ' pan.' At the proper moment the ' pan ' begins its backward movement, permitting the car to be turned *completely bottom side up*, to the end that every vestige of coal may be removed. In its dumping, *the track follows up the car*, the latter, as it is being tilted, coming in contact with heavy chains which hold it firmly to the track. Both car and ' pan ' are now returned to their first position, and the operation of loading the vessel is begun.

" The loaded ' pan ' by the movement of another lever is sent to the top of the tower, the jaws of the chute finding their position below the bottom. A gate in the ' pan ' is now opened, and the coal slides out and down through the chute. While the ' pan ' is emptying, the dumped car has been pushed out of the way by a loaded one, which takes its place, ready to be tilted into the ' pan ' when it comes down." (The italics are ours.)

Such, in general, are the machines which, according to the writer in the *Railway Era*, have reduced the cost of loading vessels with coal, *some 90 per cent.*

This is in truth a revolution in coal-handling, but the end is not yet reached, as we shall see on comparing these operations with those of the Goodwin car. In the machines just described the car is raised bodily and emptied. The coal finally reaches its place in the boat by force of gravity; but, prior to that, a whole

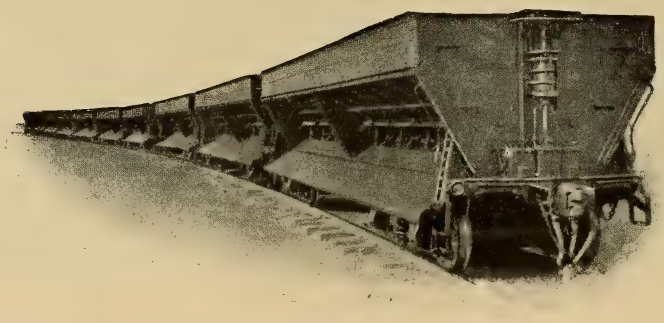


FIG. 4.—A TRAIN OF GOODWIN CARS

loaded train must be lifted, together with the track it occupies. Let one imagine a continuous train of forty cars raised and inverted by the movement of the track beneath it, and he has a picture of the operation which these machines *in effect* perform, but at a great expense of time. Next, imagine a similar train from which, by a single lever movement, and without *any* lifting of load, car, or track, the coal is at once discharged, and the essential difference between the lake stationary car dumpers and the Goodwin car is seen. The former compel a service

to the car which it was never intended to give; the latter does that service without compulsion of any sort.

All these operations of all these car dumping machines have a single end,—to get the coal onto the upper end of an inclined plane, the lower end of which leads to the boat. Once upon the plane, gravity moves it to its destination.

Now the Goodwin car carries its load in the hollow caused by the intersection of two inclined planes. In discharging the car, one of these inclined planes is removed, leaving the load unsupported upon the other. As a consequence the load slides down and out. All that is needed is an extension of that inclined plane to enable the load to slide into the boat. This extension is given by a simple permanent chute of 30 degrees slope, which may be restricted to the length of a single car or continued the length of a train.

In the former case, the train would be shoved along, car by car, at intervals of twenty seconds, the flow of coal requiring not more than six or seven seconds; in the latter case, the whole train would be discharged by air in the same length of time required to empty one car.

Or, the chute may extend the length of a vessel with the proper number of chutes to reach all its hatches, in which case the cars would be discharged in groups. In brief, the length of the chute and its subdivisions are determined by local considerations.

It is impossible to conceive a mode of discharging coal in which there is less breakage. The flow starts at the bottom of the load first, and the portions which have an initial vertical movement are deflected by these earlier moving portions, so that they receive no shock. In the case of the stationary dumping machine last described, the coal is twice dropped, first from the inverted car into the "pan," and then from the "pan" into the chute.

Now let us consider some figures:—

At a wharf 1500 feet long, five 300-foot boats may lie. A loaded train of forty Goodwin cars is run onto the wharf, and in fifteen seconds from coming to a standstill the whole train load of 1600 tons of coal is discharged by one man. The train is at once withdrawn without uncoupling, and is ready to start back to the mines. Given the necessary supply of cars and coal, this process can be repeated every five minutes. In fifty minutes five vessels would have been loaded, each with a cargo of 3200 tons, or 16,000 tons in all. This is at the rate of 19,200 tons per hour.

But if it be a single vessel that is to be loaded, then the train of forty cars is pushed forward in five successive movements, and the cars are discharged in groups of eight. Each such movement would take about two minutes, so that in ten minutes the boat would have received 1600 tons of coal, or half its cargo. This makes a rate of 9600 tons per hour.

Now let us see just what the stationary car dumpers accomplish, according to the writer in the *Railway Era*. The first described machine, which we will call No. 1, "dumps a carload of coal,—about forty tons,—into the vessel's hold at the rate of about nine carloads an hour, or 3500 tons per ten hours, or about 8500 in twenty-four hours." This is a rate of 350 tons per hour.

No. 2. Capacity not stated.

No. 3. "The capacity of the installation shown is 350 tons per hour."

No. 4. "It is claimed that the machine will handle 300 cars (at 25 tons each, evidently), or 7500 tons of coal in a day of twenty-four hours." This is a rate of 312½ tons per hour.

No. 5. "The capacity of this installation is 400 tons per hour."

No. 6. "Its celerity of operation is remarkable, it being capable of handling a car a minute. Of course, this celerity of operation is never maintained, as it is a physical impossibility for the men in the vessel's hold to take care of and keep the hatch clear for from forty to fifty tons of coal a minute." (We may

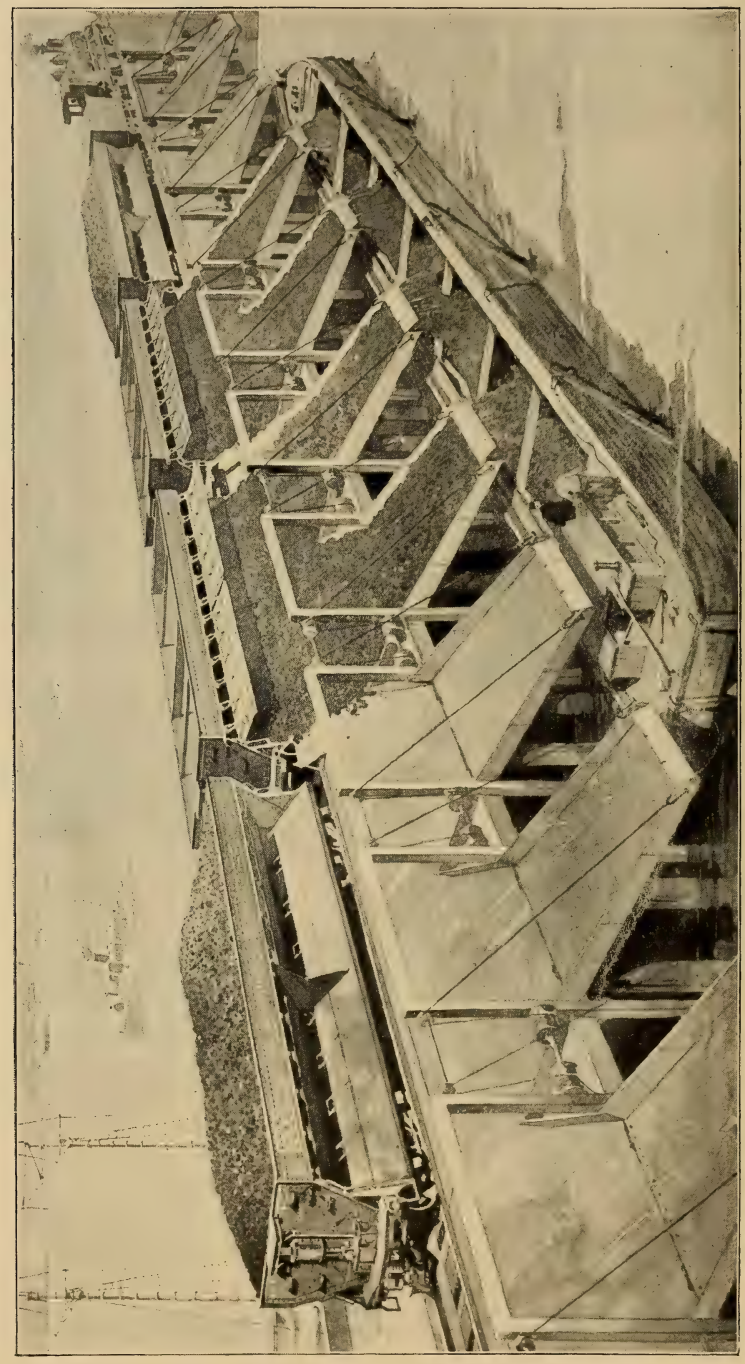


FIG. 5.—SKETCH SHOWING TRAIN OF GOODWIN CARS DISCHARGING FROM A COAL TRESTLE ADAPTED FOR SIDE DISCHARGE OF CARS, AND DEMONSTRATING THE SAVING IN DISTANCE OF DROP AND IN BREAKAGE OVER HOPPER DISCHARGE METHOD

remark here that the difficulty alluded to obviously arises from the fact that the machine and its chute are stationary; hence the distribution of the load must be accomplished by shovellers in the hold or by moving the boat so that its several hatches will be brought, in turn, opposite the point of discharge.)

As the actual loading capacity of No. 6 is not given, we must leave it to be inferred from the operations of the others. These show an average hourly capacity of 353 tons. Supposing that No. 6 in practice could attain a discharge as high as 600 tons per hour, the employment of the Goodwin car in groups of a boat's length shows an enormous contrast,—9600 tons per hour as against 600. This is a ratio of 16 to 1, and means that with Goodwin cars, fifteen hours out of every sixteen now necessary with the most improved appliances for the transference of coal from car to vessel may be saved. This proportion would be doubled,—32 to 1,—were five boats loaded simultaneously as above described. And this without the use of pockets.

The car dumping machine which unloads 600 tons an hour would hold a train of 1600 tons capacity,—forty cars at forty tons each,—just two hours and forty minutes. A train of Goodwin cars at the least favorable figures given above would unload in ten minutes. Therefore, the Goodwin train would set out on its return trip to the mines two and one-half hours earlier than the machine-dumped train. At a port where a million tons annually are shipped, there must be 625 train trips, and a consequent saving for the Goodwin train of 625 x 2½ hours, or 1562 hours of working time.

This important saving in time means a great deal. It may be roughly expressed by saying that during that length of time one has the free use of all the means of transportation,—locomotives, cars, tracks, wharves, and vessels formerly standing idle during that period,—together with the services of all the paid labor incident to their operation. The saving is gained simply by making unproductive paid time productive. The labor-time of the actual discharge is less than a minute for each car, as against sixteen minutes for the best car dumper, and eighty minutes for a steel hopper car. In estimating the value of the time saved by rapid unloading, we must consider the whole series of operations involved in getting the coal from the mines to the consumer as a single process. A delay at any one point means a delay of the process as a whole It is exactly as if each train should lose two hours and a half on the road through break-downs Everything along the whole line has to wait Coal cannot be mined faster than it is carried away, and so the output is restricted; the salaried labor all along the route from beginning to end is wasted; the whole mining, transporting, and selling plant is made proportionally unproductive; and the outcome is a reduced gross profit and a reduced percentage of net profit to gross.

The above considerations, however, do not include the whole saving assured by the use of the Goodwin car. The economies I shall briefly outline affect the railroads primarily, but indirectly benefit the shipper, by reducing the cost of freightage.

First, the initial cost of the transshipping plant for the Goodwin cars is only about one half the cost of the car tipping plant. Second, it is less costly to maintain and less liable to get out of order. As each Goodwin car is equipped with its own discharging mechanism, and one car out of order does not bring the entire unloading plant to a standstill, as is the case when a slight mishap occurs to the car tipping device. Third, it uses no fuel. Fourth, the Goodwin cars can safely be run much faster than common cars, are lighter per ton of material carried on a round trip, require less fuel in locomotive, are far less liable to breakdown on the road, and need infinitely less repair work. Fifth, their quick movement removes the need for multitudinous yard and switching tracks. Sixth, they render the shipper independent of the stationary car dumper at the place of ship-

ment. Seventh, they can be discharged at any place on the way without the necessity of shovelling the load out, and thus are equally useful for local as well as through service. Eighth, by their capacity of central as well as side discharge they can make use of all existing chutes arranged for hopper cars. Ninth, by the use of the stationary side aprons and the block and pulley fixed to side of car, any load that can pass through a box car door may be loaded into the Goodwin car from the ground without the use of a crane or a loading platform and allowed to slide out in same manner by placing skids against the apron. Tenth, the ability to carry and discharge all kinds of material under all conditions, gives a paying load in both directions, thereby increasing the earnings of the Goodwin car over any hopper type of car or any flat bottom car built.

These and other considerations which need not be here mentioned unite to give the Goodwin car an efficiency in practice which it is easier to appreciate than to state in exact figures, but which greatly increases the estimate of saving given above.

To the mine owner and shipper its superior merit is that it promotes the quick transit of his product from mine to market, permitting thereby increase of production and sale, and brings it to the market in the best possible condition, and with the least expenditure of money.

To the big furnace interests and to the railroads the superior merits of the Goodwin car are its ability to carry and discharge all kinds of way freight and general merchandise, from fine, loose material to bulky materials like pig iron, billets, large rock, heavy castings, hot cinder, etc., thus enabling the car that brings a load of coal, ore or limestone to the furnace, for instance, to be readily discharged and loaded out with any of the numerous products of the furnace, none of which can be discharged from the ordinary hopper cars, whether they are built of wood or steel. This gives the Goodwin car a paying load in both directions, relieving the railroads from the burden of hauling empty hoppers from the furnaces and empty flats to the furnaces. Any railroad handling this class of material will readily appreciate the enormous saving in this one feature alone. This gives even the heaviest Goodwin car, which is built to stand the drop of steel blooms, and billets, and heavy rock, a much greater paying load than any hopper or flat-bottom car that in itself may weigh even 50 per cent. less than the Goodwin car, in actual pounds per car; but the hopper car is only serviceable for a few special materials, and must more frequently be run empty or even stand perfectly idle when its special work is suspended, such as is the case with special ballast cars and cars built to perform one class of work only. Still another special feature of the Goodwin car for carrying coal is the method of construction whereby the frame of the car is absolutely protected from the coal acids, the stationary aprons and floor valves effectually shedding the rain water, and all of the malleable castings are dipped in carburet black before being riveted into place, and all surfaces are thoroughly coated with carburet black before they are put together. This has obviated in the Goodwin cars the difficulties usually experienced in handling coal in steel cars.

Our cut (Fig. 6) shows, in section, the Goodwin patent coal handling trestle in operation with the Goodwin patent scows, barges, and storage bins, in all of which apparatus use is made of the same mechanism that gives the better known Goodwin car its discharging efficiency.

In this section *A* is the Goodwin car on the trestle, and *R* is the Goodwin car on the return track, in position to be loaded through the chute, on the line shown by the arrow *P*. *G* is the Goodwin car on the float *H*; *K* is the catamaran Goodwin scow; *S* is the barge under the return track, in position to receive the centre discharge from the Goodwin car *R*; *T* is the barge in position to receive the discharge from the catamaran scow *K*. *B*, *C*, and *D* are the continuous pockets, fitted with discharging valves, operated in gangs. The mech-

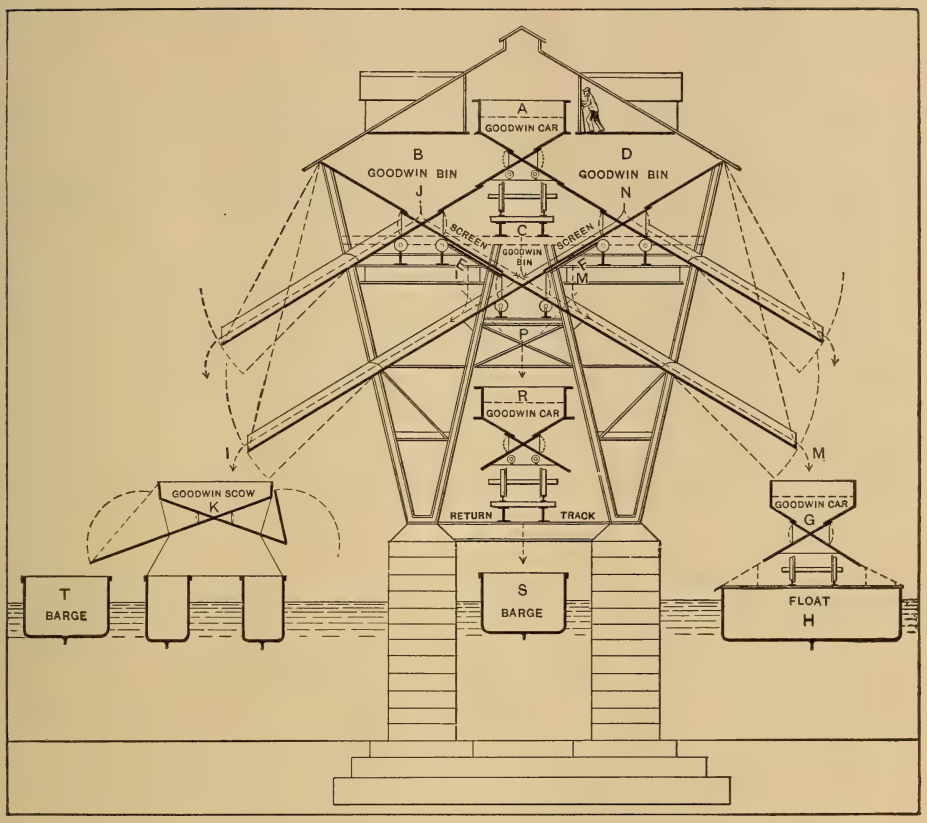


FIG. 6.—SECTION OF GOODWIN COAL HANDLING TRESTLE

anism of these pockets is similar to that used on the car, and covered by the Goodwin patent. The lines of possible discharge for the material are indicated by dotted lines and arrows. The screens, marked *E* and *F*, are utilised for screening the coal or other material as it passes over the screen. If it is desired to load the Goodwin car *G* with coal from bin *B*, the discharge would be on the lines *J*, *M*, *G*, and the screenings will follow the lines *J*, *I*, *K*, and be received in the scow *K*, on the opposite side of the trestle from the car *G*, into which the coal is being discharged. It will be plainly seen that this operation may be reversed, discharging the coal from the bin *D*, on the lines *N*, *I*, *K*, the screenings following the line *N*, *M*, *G*, or the coal may be discharged into the barge *G* from the bin *D*, following the lines *N*, *M*, *G*, or from the bin *B* into the scow *K*, following the lines *B*, *I*, *K*. When a train of cars arrives on the trestle its load may be at once discharged on either or both sides, or in the centre, and retained in the bin into which it is discharged until such time as it is desired to transfer the load from the bin into the receiving vehicle at *K*, *G*, *R*, or *S*. Still another advantage of this special construction of trestle covered by the Goodwin patent is the possibility of accommodating the discharge and storage of both hard and soft coal at the same time. This form of trestle also accommodates any of the present styles of gondolas, or hopper cars, making it possible to unload flat-bottom or centre dumping cars that may be mixed in the train with the special Goodwin cars. This trestle, as here shown, has both an upper and lower deck, especially adapting it to tide-water handling of coal and ore. The lower chute

may be used at low tide and the upper chute at high tide, thereby saving the breakage that would otherwise result from the added distance that the coal would have to drop.

This same principle is designed by the Goodwin Car Company for coaling locomotives and vessels. In this system of loading the bins are made in lengths as desired, with a given cubic capacity, using, say, four or five pockets as the full capacity of a locomotive tender, these pockets being arranged to operate one at a time, or in gangs, as desired, the knowledge of the cubic capacity of each pocket, secured by measurement, eliminating the necessity of weighing the coal as it is discharged.

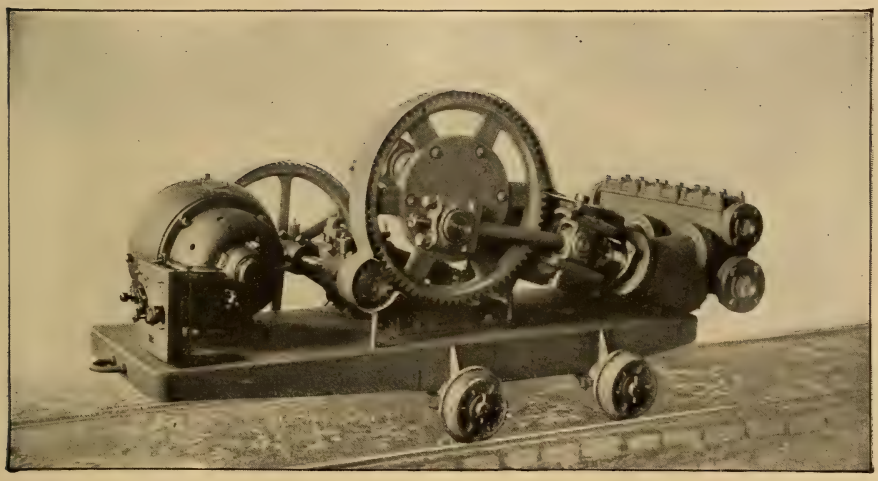
In a trestle or storage bin of this design the necessary height of the chute is the lower edge of the discharging apron of the Goodwin car, whereas with a hopper or centre discharging car, the necessary height of the chute is the clearance space under the sleepers supporting the ties and track. Upon comparing this construction with the centre discharge trestle, it will be seen that the Goodwin trestle is less than half the usual height required, and that on a dock projecting into the waterway there is only one track in width needed for the handling of a train in place of the three tracks used at present where a centre returning track is employed. In place of the usually employed automatic switch to transfer the coal car from either side track to the centre returning track by the gravity of the car, there is employed on the Goodwin trestle a drop section at the end of the pier, this section being the length of one car, and controlled by water gates, which drop with the car to the line of the return track under the coal pocket. This drop section resumes its original position as soon as the weight of the car is removed, and is ready to drop with a following car in about one minute's time.

The merits of the Goodwin patents for handling all dumpable materials under all conditions have been generally acknowledged, and set forth in a number of published articles; but the special features for the handling of coal, ore, and limestone here shown have not until recently been given to the public.

JOHN M. GOODWIN.

ELECTRICALLY-DRIVEN TRIPLEX MINE PUMPS

ELECTRICITY as an agent for transmitting and distributing power has rapidly come to the front, and has been widely adopted as the most economical in cost and convenience of operation in the various mining industries. Its application is found in the actual mining by electrical cutters and mining machines; in the transportation to distributing points by electric locomotives; in the lighting of mines; and, not the least important, in the disposal of the troublesome mine water by electrically-driven pumps. These pumps are made for direct connection to motors, in both stationary and portable types, and in many sizes, by The Deming Company, Salem, Ohio, who have for many years given special attention to this class of work.



PORTABLE ELECTRICALLY-DRIVEN TRIPLEX MINE PUMP

The stationary type can be located at any convenient place in the mine, can be started and stopped from any point desired, and requires but very little attention other than the occasional oiling of bearings.

The portable type, shown in the accompanying cut, has the advantage over the stationary pump in that one pump can be moved around to serve several portions of the mine, and thus reduce the number of units required. They are made for any gauge of track. Both types can be direct connected with any type or make of motor.

The compactness of design and the ease and economy of operation of pumping outfits of this class should appeal to all mine operators who have electric power available, and any information desired will be gladly furnished on application.

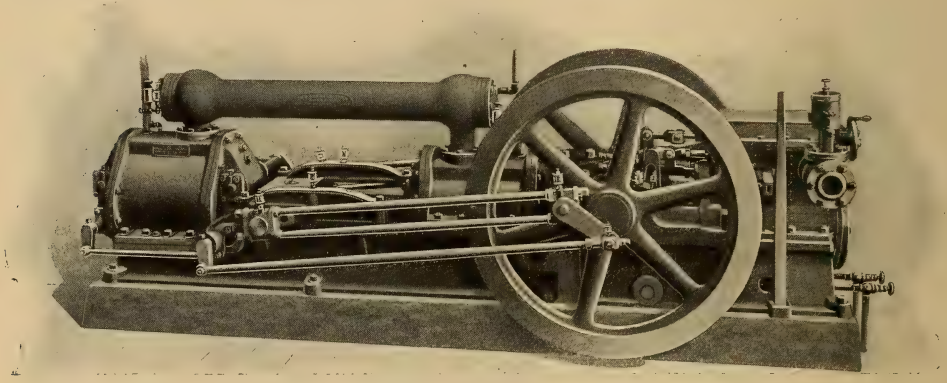
THE DEMING COMPANY, SALEM, O.

NORWALK AIR COMPRESSORS

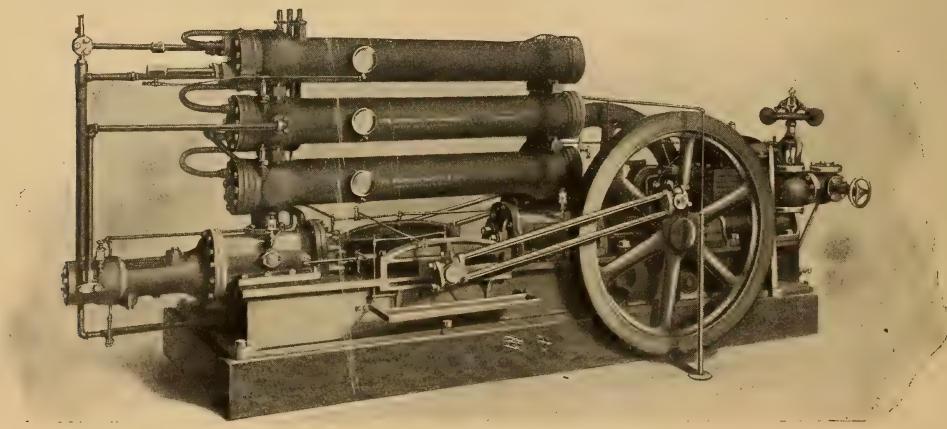
WE will not attempt to engage your attention by an apparently scientific article on some interesting technical subject or a popular description of a great engineering undertaking, and then at the supreme moment hold you up to announce that we made all the machines used in the work, but we will come to the point, "butt end, too," and announce right here that our business is the manufacture and installation of compressors for every possible use.

We have been leaders in this business for thirty years, and have not only served with satisfaction some of the most critical and best qualified operators, but have received the endorsement of the most distinguished body of engineers of this century, viz., the International Commission of Engineers for considering projects for the improvement of Niagara Falls.

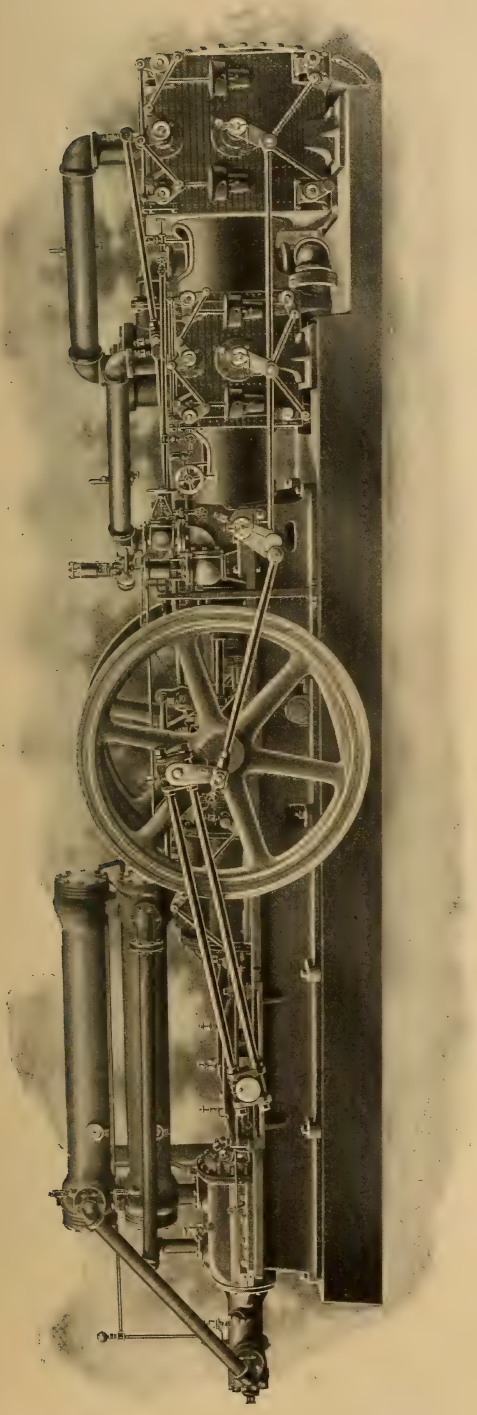
Our machines are used from Alaska to South Africa, and the sun in his daily course is constantly cheered by the sight of a Norwalk compressor.



For railroad switches, signals and shops; for manufacturing, riveting and hoisting; for gold, silver, iron, lead, tin, copper, salt, asbestos, cement, coal, and mining and quarrying of all kinds the Standard Norwalk compressor, with its compound air cylinders, positive Corliss air valves and intercooler, is the machine



NORWALK AIR COMPRESSORS



par excellence that has always been the dependence of the owner and the admiration of the observer.

For extremely high pressure, 3,000 to 5,000 lbs. per square inch, we have a complete line of compressors. Where expedient we use ante-coolers, intercoolers and aftercoolers. The same general style, with modifications of detail, is also used for carbonic acid gas, acetylene, oxygen, hydrogen, Pintsch gas, etc.

For pneumatic locomotives in mines the popular machine is the three-stage machine with two intercoolers. This pattern is made with single steam cylinders and compound or triple expansion, as may be desired.

Our new Foundry Special Compressor is of great interest to manufacturers making use of two air pressures—as twenty-five pounds for cleaning castings, blowing chips, etc., and one hundred pounds for driving hammers, riveters and similar tools.

The action of the compressor is automatic, delivering to the different pressures as the demand may be—all to the low pressure, or all to the high pressure, or any percentage to the low pressure and the balance to the high pressure, automatically changing the percentage, and varying its speed as required.

A review of the Norwalk Compressor is not complete without special notice of its performance in the transportation of natural gas. Four hundred million cubic feet per day is the capacity of the Norwalk Compressors, pumping this most wonderful gift of Providence to man.

For all distances, from a half-dozen leagues up to one hundred and thirty-two miles, the compressors perform their work with certainty and reliability continuously day and night, the sole dependence of factories and large cities for artificial heat and light.

A thousand minor uses of air are best supplied by some one of the many forms in which we make the compressors. We publish catalogues, and are always pleased to tell the responsible engineer, operator or manufacturer how we can best serve him.

THE NORWALK IRON WORKS CO.

South Norwalk, Conn.

STURTEVANT TOGGLE SEPARATOR

INCLINED Shaking Screens, although comparatively new, have, because of their extraordinary *capacity*, nearly displaced all other separating devices within their field of usefulness. It would be untrue to say that *durability* has not also been an important factor in their adoption. Inclining a screen has much the same practical effect as reducing the size of its meshes, and, therefore, a comparatively coarse wire on a steepily pitched screen may be used for fine separations. This explains their lasting qualities, for that heavy wire clothing is more durable than delicate constructions is obvious. Inclined Separators are also cheap, because they are ready to run as soon as a bolt is attached without any boxing, hoppering, or setting up expenses. All these good points have become known, and are appreciated.

The Sturtevant Mill Company, of Boston, Mass., has made special studies of screen constructions, and effected important improvements in inclined screens. Their separators have four screens (48 square feet in all) placed, and firmly held, one over another, in a strong box, 2 feet wide and 6 feet long. Each screen is a substantial construction and easily handled, for it is *small*. Each receives equal feed, evenly spread over the wire surfaces. One outlet discharges the tailings, another the fines. No conveyors are used to carry *in* or *out*, or to spread material. They are not needed. Gravity does it all.

It has been found to be practically impossible to spread any substance evenly over a large screen. Wide separators are weak affairs. They take up *four times* the room of Sturtevant constructions. In the Sturtevant Separators the screen box is *supported on springs* and shaken by a toggle. The toggle has no *lifting* to do. It has only to *shake*, and this it does *four* times for each revolution of the driving pulley, which does not have to run fast, and moves so easily that the power required is but a small fraction of that used by any other screen of large capacity.

The toggle is an ideal vibrator for screens, and besides being simple, is scarcely harmed at all by grit. Toggles have the same durability in screens as in the Roll Jaw Crushers made by the Sturtevant Mill Company.

The improvements described have reduced Inclined Separators to one-quarter their former size, and have given strength and durability to the only weak points of a most valuable invention. By setting the toggle so as to vibrate the box and its screens *vertically*, another advance, securing a further increase in the well-known capacity of Inclined Separators, has been attained.

It was noticed that an inclined screen, *vertically* shaken, throws the material upon it upward in vertical lines. This can then, obviously, only *fall* back to the point from which *it started*. Thus no material can pass over the screen while *in the air*. It can only slide down while *on the wire*. Thorough screening was seen to be thus accomplished, all the surface being used. In no Inclined Shaking Screens (except the Sturtevant) are the particles thrown vertically; they are always projected in a *forward* direction, and *dropped vertically* from the point where the upward movement ceases to a point on the screen considerably *below where they started*. Thus the material in all common screens passes down *while in the air* by leaps and bounds, and *skips* much of the screening surface. Vertical vibration requires no theory to explain its practical advantages. It proves itself in very considerably increased outputs.

Sturtevant Toggle Separators are good, because they belong to a class of *good* things; but they are the *best*, because they alone have perfectly efficient screening surfaces, and do more work, last longer, and only occupy *one-fourth* the space of other machines. All Inclined Vibratory Separators may be clothed with perforations varying anywhere from ½-inch to 200 mesh, as ordered.

STEEL HEAD FRAMES

Constructed by

THE WELLMAN-SEAVER-MORGAN ENGINEERING COMPANY

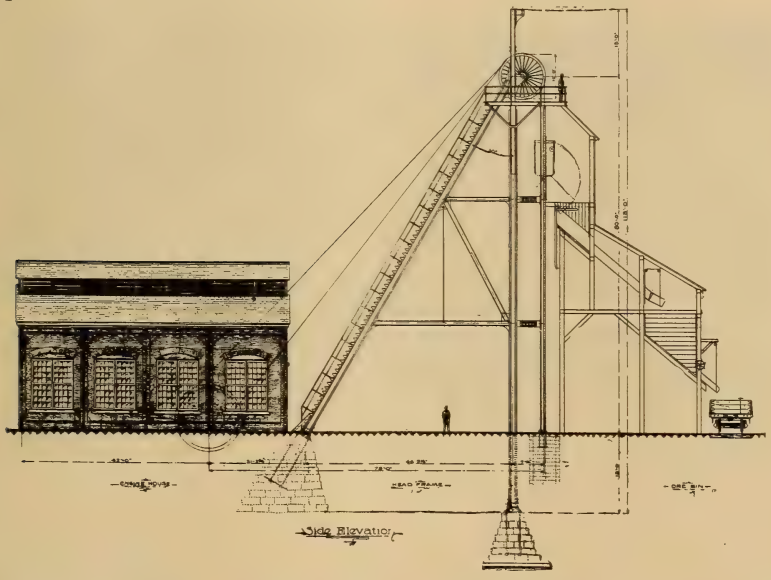
Engineers and Manufacturers

CLEVELAND, OHIO

AMONG the notable changes which have taken place in mining engineering in the last few years is the substitution of steel construction for wooden framing for head frames and other similar purposes. The reasons for this substitution may be noted as follows:

The decrease in cost of construction. The timbers necessary to afford sufficient strength for a head frame are of such size that they are very costly, especially when the transportation, often to a remote mining camp, has to be taken into account. The timbers are required to be not only of large section, but in order to have the necessary stiffness it is essential that they be in one length as far as practicable. The joining of these timbers to each other is a very difficult problem, the necessary mortises for the tennons weakening the timbers to a great extent.

By substituting steel for wood, a light, and at the same time stiff, construction is obtained, and the various members can be put in the exact lines of strain and proportioned for their various loads.



At the present price of steel it can be substituted for wood at a less cost, and, because of difference in weight, cause a saving also in transportation. The greatest advantage, however, in the use of steel head frames and gearing is the minimizing of danger of loss by fire, since in this way it is possible to make the head frame and head house entirely fireproof. It was the careful consideration of the above points that led the Wellman-Seaver-Morgan Engineering Company, of Cleveland, Ohio, to adopt this method of construction of head frames, and they are among the pioneers in this line. Among their notable pieces of mining work may be mentioned the great steel head frame of the Anaconda Copper Mining Company's St. Lawrence Mine at Butte, Mont. This is built to sustain the maximum loads that can be brought upon it from hoisting from a depth of 5,000 feet with two flat ropes, 8 inches wide and 5/8 inch thick. This head frame has attracted a great deal of attention.

The Bleichert System of Wire Rope Tramways

MANUFACTURED BY

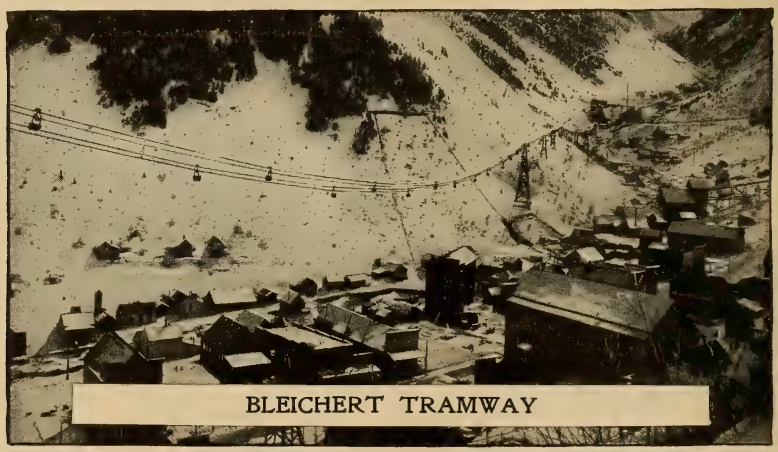
THE TRENTON IRON COMPANY

TRENTON, N. J., U. S. A.

NEW YORK: Cooper, Hewitt & Co., 17 Burling Slip.
CHICAGO: H. N. Elmer, Mgr., 1114 Monadnock Building.
DENVER: R. D Seymour, Mgr., 1711 Tremont Street.
SAN FRANCISCO: Newton M. Bell, Agt., 308 Market Street

CABLE ADDRESS, "YAWMART, NEWYORK."

IN THE "BLEICHERT" SYSTEM of wire rope tramways, the loads are suspended from carriages which run on stationary cables, and are moved by a light, endless traction rope, to which they are attached, and which travels continuously about terminal sheaves. This is the general distinguishing feature of the system and has led to its being known as the "Double-Rope" system, in



Of the Bunker Hill and Sullivan Mining and Concentrating Co., Kellogg, Idaho, showing portion of a span of 1,173 feet across the town of Wardner.

contradistinction to the "Single-Rope" system, in which one rope performs both functions.

The Bleichert System is adapted to the transportation of all kinds of material, and is especially recommended for heavy service and mountainous localities. *Special attention is invited to our* PATENT LOCKED-COIL TRACK CABLE *and the* WEBBER PATENT AUTOMATIC COMPRESSION GRIP, which features have contributed more than anything else to the high standard of economy attained in the Bleichert System, and its superiority is attested by the fact that there are more Bleichert tramways in use than all similar systems of aerial transportation.

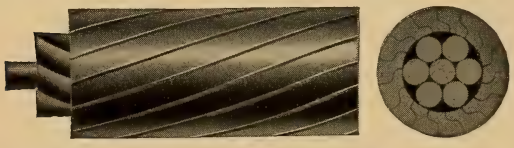


Fig. 1. Patent Locked-Coil Track Cable.

THE TRACK CABLES

The track cables are of special construction, and are known as the " Patent Locked-Coil Cable " from the fact that the outer wires are of such shape that they interlock with each other, as shown in Fig. 1, presenting a smooth surface,

Fig. 2. Patent Coupling.

and yet possessing sufficient flexibility to be shipped in coils. The difficulties heretofore experienced with other track cables, resulting from fractured wires and a ragged surface, have been entirely obviated in the PATENT LOCKED-COIL CABLE, which gives the highest degree of service with a minimum wear on the carriage wheels. It is made of a select grade of steel, in lengths from 800 to 1,400 feet, which are joined by patent couplings. (Fig. 2.)

These couplings are made in halves, each of which embraces a funnel-shaped aperture, into which the ends of the cable sections are socketed, the two halves being joined by a plug with right and left hand screw-threads.

The track cables are stretched to a safe working tension by means of counter-weights, applied at one or the other of the terminal stations. In lines of great length, however, it becomes necessary, on account of the saddle friction, to apply tension at intermediate points also, the location of which will vary from 3,000 to 6,000 feet apart, according to the contour of the ground. The track cables are parted at these points, and the ends either rigidly anchored, or counter-weighted, as the case may be, the arrangement being such that each cable section is anchored at one end and weighted at the other, the weights being applied usually at the lower end. The cars at such intermediate tension stations pass from one section of cable to the next by means of intervening shunt rails, so that no interruption occurs in the continuity of the track.

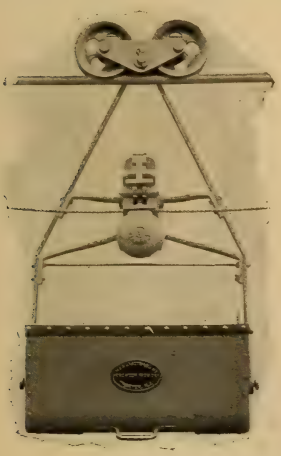


Fig. 3.
TRAMWAY CAR
Fitted with Webber Patent Automatic Compression Grip.

THE ROLLING STOCK

The ordinary car, such as used for transporting ore and like material, is illustrated in Fig. 3. The complete car, it will be observed, consists of a carriage which runs on the track cable, a hanger depending from this which supports the bucket, and a grip, by means of which the car is attached to the traction rope. When the cars arrive at either terminal, or other station, the grips detach automatically and the carriages are switched off on to the shunt rails, supported by the structure of the station, by means of which they are conveyed to the points of loading or discharge, as the case may be.

The WEBBER PATENT AUTOMATIC COMPRESSION GRIP *with which the cars are fitted can be used on the steepest grades. It requires no buttons, lugs, or knots of any kind on the traction rope, and the troubles incident to the slipping of these are entirely avoided. A great economy is also effected in the wear of the traction rope, owing to the fact that this is not confined to certain spots, but is distributed over the entire rope. Besides detaching automatically, it can also be attached automatically to the traction rope if desired.* This

grip has proved so satisfactory in all the numerous lines on which it is now operated that we have abandoned the old friction and lug grips formerly used. Some of these lines were originally equipped with the older grips, but have been changed to the Webber grip, on account of the economy effected in the longer life of the traction rope.

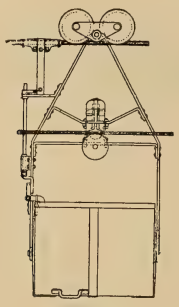


Fig. 4.

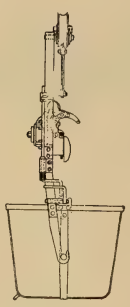


Fig. 5.

Self-dumping Bucket.

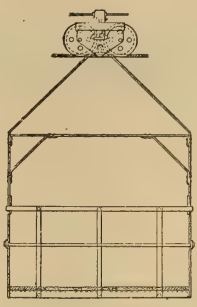


Fig. 6.

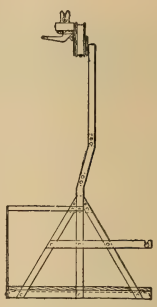


Fig. 7.

Bale Carrier.

Self-dumping buckets are furnished when required, as shown in Figs. 4 and 5. A short bar attached to the track cable, at any desired point for dumping, disengages a latch attached to the hanger, releasing the bucket, which is so hung that it instantly discharges its contents.

Special receptacles are made to suit the material to be carried. Figs. 6 and 7 illustrate the bale carrier used on a line built for the Plymouth Cordage Co., Plymouth, Mass., which at one point makes an angle of ninety degrees, around which the carriers pass without detaching from the traction rope, it being necessary in such cases to run the traction rope above the track cables, requiring a grip attached to the carriage, as shown. The successful operation of this line for several years has demonstrated the possibility of passing bends automatically, and marks an advance in the adaptabilities of this method of transportation.

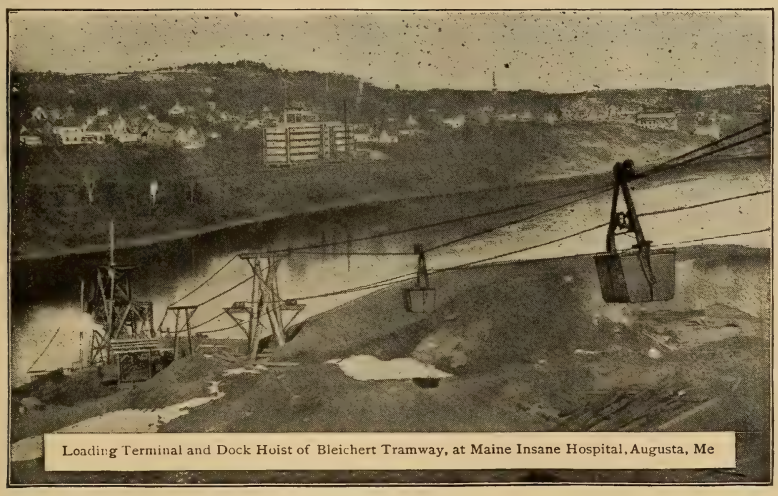
THE SUPPORTS

The supports may be of wood or iron, as preferred, one of each of the tower

BLEICHERT TRAMWAY

Of the Solvay Process Co., Syracuse, N. Y. Showing both wood and iron supports.

pattern being shown in the view of the Solvay Process Company's line. Other designs are made to correspond with the service and special conditions of the location.



Loading Terminal and Dock Hoist of Bleichert Tramway, at Maine Insane Hospital, Augusta, Me

The spacing of the supports depends altogether on the contour of the ground. On level stretches the distance varies from 100 to 200 feet, according to the capacity of the line In mountainous localities the distances between supports

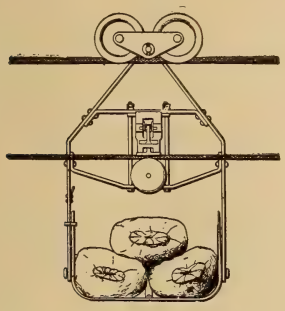


Fig. 8. Sack Carrier.

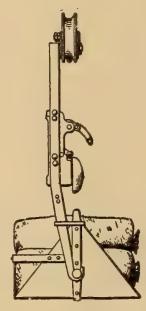


Fig. 9.

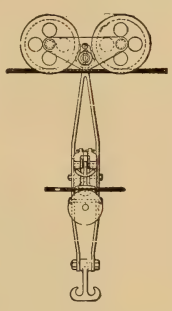


Fig. 10. Package Carrier.

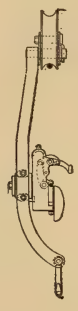


Fig. 11.

will vary greatly, being closer on the ridges and wider apart in the valleys. If the ridge is a sharp one, stations are sometimes located on a summit, consisting of a series of bents, 15 to 20 feet apart, supporting rails which overlie the track cable, saving them from undue wear, which would otherwise occur at such points. In crossing ravines, valleys and rivers, on the other hand, clear spans have been made up to 2,200 feet, one of this length occurring in the line of the Silver Lake Mining Company, Colorado. To determine the exact number and height of the supports therefor it is necessary to have a profile made from an accurate survey of the route over which the line is to run.

We also design and manufacture equipments for wire rope tramways adapted to special conditions.

For further particulars, address

THE TRENTON IRON COMPANY

Trenton, N. J., U. S. A.

Edson's P. & M. Outfits Disposing of a Superabundance of Water. Capacity, 4,000 gallons per hour.

Edson's P. &. M. Outfit Dismounted, *En Route* Through 25 Miles of Wilderness.

Edson's P. & M. Outfit Conveying Water from a Distance to Operate Sluice. Capacity, 4,000 gallons per hour.

A MODERN OUTFIT

Many Difficulties Overcome by the Use of Edson's Diaphragm Pumping Apparatus

PROSPECTORS and Miners are often confronted with the problem of providing for a scarcity or superabundance of water in places where a steam pump would not be required and where the sand and grit in the water will not permit the use of an ordinary plunger pump.

The *Edson Prospecting* and *Mining Outfit* is especially adapted to meet the requirements of Prospectors and Miners. Being simple in construction, one of its chief features is the ease with which it can be taken apart, neither skill nor experience being necessary in setting up and connecting the hose. The facility with which the parts can be carried on the backs, or transported by mules, are advantages which must appeal to every *miner* and *prospector*. These advantages, together with the powerful Suction and Discharge, are derived from the Edson Diaphragm System, while the angular inlet valve minimizes the possibilities of clogging and admits of the free passage of thick sediment, slime, tailings and clayey soil.

The Edson Outfit is invaluable for Gold placer workings, for draining pits, and forcing water up hillsides or elevations for gravel washings, where a waterhead would be otherwise unobtainable. Water can be conveyed a distance of 1000 feet by this system, which enables one to work many rich spots now abandoned or never touched through lack of means for obtaining a water supply. In mining operations water frequently accumulates in the bottoms of "drives." With an Edson Outfit this may be easily and quickly conveyed to the main shaft, while the Outfit can be carried to any location in the mine where water has to be removed.

An idea of the enormous capacity of these Outfits may be had when it is stated that *TWO MEN* with a No. 10 Pump have freed a mine of water at the rate of *6000 gallons per hour*. Capacity of Pumping Outfits from 1500 gallons and 4000 gallons per hour operated by one man, to 6000 gallons per hour operated by two men.

A prospector's or miner's equipment is not complete without an Edson Outfit, and it will be found most advantageous and profitable to write to the manufacturers for a free booklet describing the various Outfits and giving the names of some of the users, among whom are the most prominent Mining Companies in the World.

EDSON MANUFACTURING COMPANY,

132-136 Commercial Street **BOSTON, MASS., U. S. A.**

Manufacturing Department

THE VALUE OF COST ANALYSIS

By George F. Watt, Manager of the Baker-Vawter Company, Audit Department

TO keen competition is due the progress of the world, but unequal, ignorant competition has forced as many industries to suspend as has any other cause. Unintelligent competition demoralizes the trade of every concern engaged in the same line. The manufacturer who makes the lowest and most widely varying prices is generally the one who has never made an intelligent effort to analyze the cost of his product. He is usually the one who sells for 90 cents what it costs him a dollar to produce.

The successful, prosperous firms, who pay the best wages, command the trade of the highest class, and build up an enviable reputation, are those who know the exact cost of every article they produce, and secure that knowledge promptly.

THE VALUE OF COST ANALYSIS

Accounts should be so kept that at the end of each month a statement of the business in detail can be made, showing the cost of every article. Modern accounting systems will show such results with less expenditure therefor than most methods employed in the last century, which at best only partially analyzed the business.

It is not necessary to figure cost on each article as produced, unless it is very large or special in construction, and few concerns who attempt to do so get accurate or satisfactory results.

Product costs can easily be obtained without very much expense or labor if the accounting system as a whole is harmonious and flexible.

Commencing with the purchase accounts as a basis, and making an intelligent classification of all materials and expenses, the average cost of every article can be secured by ascertaining the cost of the entire product thereof each month.

A detailed analysis of the product, as well as of the departmental expenses, can be secured without any excessive amount of labor, and proves of inestimable value in every business to which it is intelligently applied.

The moral effect upon employees, whether they be in authority or not, is sure to be good, and tends to economical administration.

The saying, that "The wastes of one decade are but the profits of the next," is best exemplified in the American manufactories. Without accounting in any way for materials used, many institutions lose enough each year to pay a handsome dividend.

The writer can recall one concern where a change in management secured for the business a healthy overhauling which resulted in sufficient antiquated and spoiled stuff being thrown into the scrap heap to yield more than enough from its sale to pay for a complete modern accounting, stock and cost figuring system.

The employment of loose-leaf binding and filing devices for cost and stock records, as well as for the general accounting system, together with other modern appliances, so facilitates the work of the clerical force that comprehensive statements of the condition of a business can be secured in a very short time after the close of the month's business.

The above illustration represents the most generally useful loose-leaf binding device. It can be applied to any record, will hold more securely than a bound book one sheet or one thousand sheets. A leaf may be inserted or removed instantly from any portion of the binder without disturbing another. Any classification of matter can be made, including several self-indexing arrangements.

All friction being removed, the capacity of every clerk is materially increased and much saving effected.

In a large mercantile house where costs had never been satisfactorily figured a complete loose-leaf system was installed which enabled them to handle twelve per cent. more business than the previous year, with a saving in clerk hire of over $6,000, and besides they secured a comprehensive statement of results which has proven of untold value in determining the policy of the business.

The merchant or manufacturer who disregards cost analysis places a dangerous weapon in the hands of his competitors.

POWER PLANTS FOR MINING

FEW industries in the world are pursued under such varying conditions as that of mining, of wresting from the earth the treasures concealed from the eye of man in every conceivable fashion. Now it is piercing a mountain, to follow a thin streak of gold or silver ore thousands of feet downward; again, it is digging out great caverns of coal; again, whole mountain sides are grooved and plowed and pulverized for the iron that lies in them; and, again, a narrow hole is bored into the plain to tap a reservoir of oil or gas.

Possibly the work may be conducted in a centre of civilization, where the latest designs of machinery are accessible, where transportation from the workshops presents no serious problems, even of expense, and where skilled and intelligent labor is plentiful. But it is just as likely that the work must be done in some remote corner of the world, where transportation for heavy machinery involves almost insurmountable difficulties, where ordinary supplies are inaccessible, and where the weakest and most unreliable factor in the whole business is the character of the labor to be had. The intelligent and resourceful man to be found in the mines of the United States is as widely separated from the toiler in the Siberian mines and the laborer of Mexico as is the electric locomotive, with its delicate adjustment, that whisks through the long caverns of the Pennsylvania coal mines, from the crude ladder up which the peon toils with a handful of ore.

Almost as old as agriculture, the mining industry presents conditions throughout the world even more varied than that of crop-raising. While it has developed with the centuries in some portions of the world until we find the elaborate system now in use in leading American mines, there are many points where it has scarcely advanced beyond the methods of the time of Tubal-Cain. And one can find any stage of development in operation at present, from the most primitive to the most modern.

Wherever mining develops beyond the stage of the hand windlass, Atlas engines and boilers begin to demonstrate their value in the industry. The product of the great Atlas plant ranges all the way from the convenient portable outfit that can be dragged anywhere by mules and used to do all the hoisting and pumping for a small mine in the Andes, to the great Corliss engines and battery of high-pressure boilers used to generate the electrical power for the most elaborate modern mining equipment. Where masonry is a practical impossibility and transportation is difficult and expensive, the Atlas has a power equipment that fits the circumstances, and where every adjunct for the construction of a great modern power plant is at hand again the Atlas can fit it out in a thoroughly satisfactory way.

And the same qualities—simplicity, durability and economy—that win for it praises from the expert engineers of the United States have given it its wide popularity in Mexico, South America, Japan and other parts of the world where skilled labor is rare. The native fireman or helper does not throw the Atlas out of order the moment he puts his hand on it—indeed, it is no unusual thing to have a native engineer running an Atlas engine successfully. More than one manufacturer, building machinery that gives satisfaction in the domestic trade, where conditions are right, has had the bitter experience of having an expensive engine and boiler practically abandoned by their purchaser in a less highly civilized land because some little thing got out of order and there was nobody within reach possessed of sufficient mechanical genius to fix it. In years of experience with

such trade the builders of the Atlas have never been troubled with complaints on this score. Their engines are of such simple construction that the possibility of trouble from inexperience is but slight. They are built so honestly that "accidents" do not arise from internal causes. And when a part is broken by some extraneous accident, or is worn out by decades of service, the thing is so simple that the native blacksmith can make one that will run the engine until a duplicate can be obtained from the factory—and there are always duplicates on hand for immediate shipment.

Recent developments in long-distance transmission of power have made it possible to carry the energy of a mountain torrent many miles over a slender wire to operate a mine or milling machinery, but experience with the variation of the seasons shows that where anything like the full head of water-power is used it is essential that a reserve of steam-power be held in readiness for the exigencies of drouth and freezing weather.

There are mines in the mountains reached by neither railroad nor wagon track, where such machinery as can be had must be carried up steep and narrow paths on the back of a pack-mule. To meet this necessity the Atlas Engine Works build a class of small boiler that can be shipped in parts and riveted together on the ground, and an engine with the heavier parts sectionalized so that no section of the outfit weighs more than 300 pounds—a comfortable pack for a mountain mule. For the average mountain work where transportation on wheels, though difficult, is possible, nothing fits the case quite so well as the Atlas internal-fired boiler. Short, compact and stoutly built, there is not an inch of unnecessary room or a pound of unnecessary material about it. For the mine of moderate production, where a small power outfit for general purposes is desired, this style of boiler with an Atlas plain engine makes an ideal combination. And as the magnitude of the operation varies on up to the necessity for a complete equipment of electric or compressed air machinery requiring power in very large units, there are Atlas engines and boilers to fit each situation.

The power plant is an investment of importance, whether it be large or small. It is what makes "the wheels go 'round," and when it stops, the business of the mine is at a standstill. One of the problems of the mine owner, whether he be operating a great colliery or a little mine up in the mountains, is to reduce to a minimum the delays arising from breakdowns in his power. The Atlas Engine Works, in building over 22,000 engines and a still greater number of boilers, have come nearer solving this problem for the miner than any other of the world's engine builders. Strong and durable, many of their engines have been in service more than twenty-five years, and are still doing excellent work. Extremely simple in construction, there are no uncertain adjustments to get out of line or complications to puzzle an engineer. Made of honest materials, with honest workmanship all the way through, there are no parts that break when the strain comes. Built on scientific lines, and economical to a degree, the Atlas engines give as much satisfaction at the copper mine, where fuel is often precious, as at the mouth of the coal pit, where fuel is not much of a factor in the expense account.

These are the qualities that have carried the Atlas engine all over the world wherever men use the magic of steam to produce wealth. The trade methods of the Atlas Engine Works have been neither unusual nor "strenuous." They have been confined almost exclusively to the organization of a convenient and satisfactory system of distribution. It is the excellence of the product that has built the industry up from a little shop doing a local trade to one of the largest manufacturing plants of the Central West, located at Indianapolis, supporting thousands of people and doing a world-wide business.

THE ATLAS ENGINE WORKS,

Indianapolis, Ind.

Manufacturing News

Improved Chopping and Shaking Grates

THE grate bars for the furnace of a steam boiler are usually regarded as being merely mechanical appliances for supporting the fire and for admitting air to the burning fuel by means of suitable openings. Beyond that the grate bars are not generally regarded as being of particular importance in the economy of a furnace. Of course, it is well understood that one grate bar may be better than another because its air openings are better proportioned to the fuel requirements or because of its mechanical construction which makes it more durable and more easily handled by the fireman; but, aside from these features, it is not commonly believed that one grate bar could show a pronounced efficiency over another. For this reason the result of tests made on the improved Reagan grate will be found most surprising and interesting to engineers and owners of power plants. Of these we will not make specific mention in this description beyond that they demonstrate it possible to increase the efficiency of a boiler over another using an ordinary grate to such an extent that in some cases a portion of a battery has been put out of use where before the whole of them were required.

The annexed illustrations show the general features of the grate. Fig. 1 shows the choppers and fire-bars removed from one-half the grate, and Fig. 2 is a sectional side-view showing the connections to the choppers by which the fire is cleaned. As indicated by the

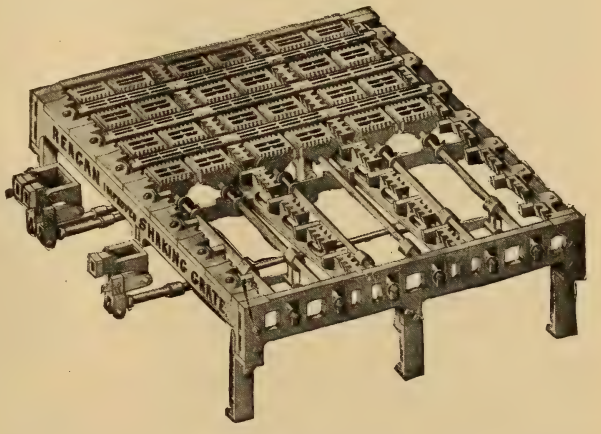


FIG. 1.—IMPROVED SHAKING GRATE, MADE BY REAGAN GRATE BAR CO., PHILADELPHIA, PA.

latter cut, one portion of the fire may be cleaned without disturbing another.

All parts of the grate are interchangeable. There are no bolt connections exposed to the fire, and the whole grate

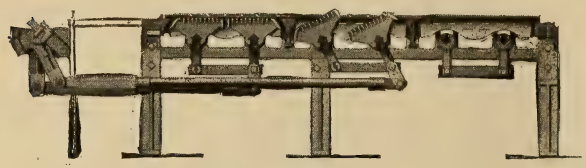


FIG. 2.--SIDE VIEW

floats, so there is no chance for any part to bind and work hard because of expansion and contraction. Consequently the grate works as easily hot as when cold. We are assured that the parts will stand very hard firing without damage, and that a fire can be kept running indefinitely without cleaning if properly handled. It is possible to burn as high as fourteen pounds of coal per square foot of grate area per hour with ordinary draught, and for this reason the grate is said to be superior to an automatic stoker in many cases on account of the increased efficiency of the furnace, and the fact that it operates on less draught than most stokers require for successful operation.

The grate is made by the Reagan Grate Bar Company, 209 North Front street, Philadelphia, Pa.

A Portable Electric Air Compressor

FOR portable service the Christensen Engineering Company, of Milwaukee, Wis., are turning out an air compressor, with the automatic governor and air reservoir, on a suitable hand truck which can be easily and quickly moved wherever necessary. This portable outfit, shown in the annexed cut, has a wide field of usefulness wherever pneumatic tools or other compressed air appliances are used and an expensive system of piping is not desirable. The compressor is taken to the work instead of transmitting the compressed air from a stationary compressor at a distance.

These compressors are frequently mounted on a waggon instead of a hand truck and transported by horses for use in drilling and bonding rails, etc., in electric railway or other work where electric power can be obtained. It is only necessary to make a connection to the trolley wire by a hook or pole for the purpose of obtaining power for the motor.

The Stow Multi-Speed Motor

THE new type of four-pole, multispeed motor shown on the opposite page, combines all the advantages of the ordinary multi-polar motor with the added advantage of an operative speed range of 100 to 150 per cent. from minimum speed, the percentage of speed variation increasing with the size of the machine. The armature rotates in a balanced magnetic field under all conditions of speed, this magnetic balance being secured by a simultaneous radial adjustment of the four "plungers" by means of bevel gearing, a hand wheel, by which the plungers are moved, being located conveniently at the top of the machine.

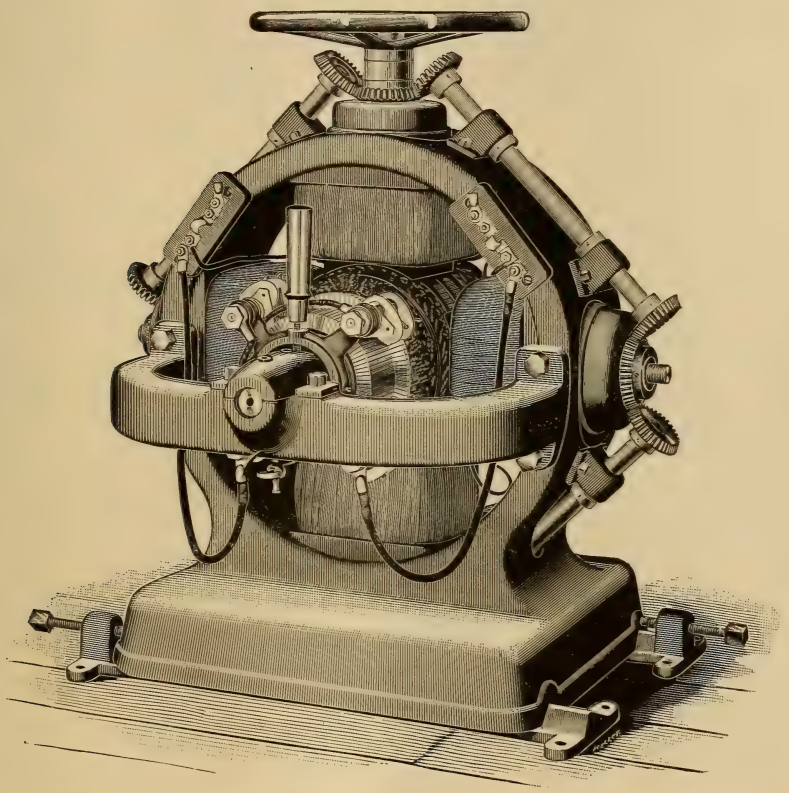
The design of the pole pieces and the selection of gearing is such that no great effort is required at the hand wheel in order to move the plungers against the

A PORTABLE AIR COMPRESSOR, MADE BY THE CHRISTENSEN ENGINEERING COMPANY, MILWAUKEE, WIS.

tractive power of the field magnets. As the gears are small and the gear rods lie close to the frame of the motor, this mechanism does not detract from the otherwise symmetrical and pleasing design of the machine.

The base of the motor is cast in one with the frame, and is provided with V slots at each of the corners, the rails being adapted to fit within these slots. While the cut shows an open type machine, the design is such that if an enclosed motor is desired, the armature supporting brackets may be removed and the ends of the frame finished so as to receive suitable enclosing heads, in the centre of which the armature bearings are arranged.

The 6 horse-power machine shown in the cut is designed for a minimum speed of 700 revolutions per minute, the maximum speed being 1500 revolutions, giving a total speed variation of 115 per cent. at any speed between which limits the machine develops its full rated horsepower with an efficiency of only 2 per cent. less at its maximum than at its minimum speed; hence the makers' claim that the motor may be operated at any speed within the limits of 115 per cent. variation, the efficiency of the motor at a given load being practically independent of the speed at which it is operated.



MULTI-SPEED ELECTRIC MOTOR MADE BY THE STOW MANUFACTURING COMPANY, BINGHAMTON, NEW YORK

The construction of the pole piece and plunger is similar to that used in the bipolar form, the field strength, consequently the armature speed, being varied in accordance with the position occupied by the pole-piece cores or "plungers."

When the plunger is adjusted so that its inner end comes in contact with the

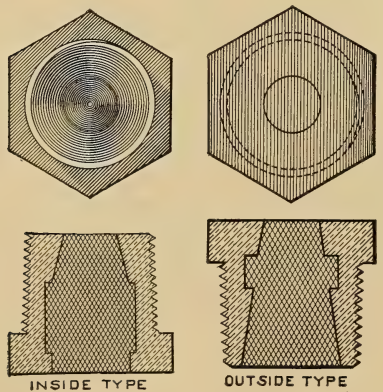
pole shoe the magnetic circuit is most complete and of minimum reluctance, and, since the E. M. F. of the field coil remains constant, the volume of magnetic flux becomes a maximum and the speed minimum, or normal. As the plunger is being drawn away from contact with the pole shoe a column of air is interposed which gradually increases the reluctance of the magnetic circuit as long as the plunger continues to be withdrawn. When the plunger reaches the limit of its outward motion the reluctance of the magnetic circuit and hence the speed becomes maximum.

To those familiar with the action of field-regulated shunt motors of ordinary type a variation in speed of 115 per cent. by a corresponding variation of the magnetic flux would seem impossible of realisation on account of the difficulty of securing sparkless commutation when the field strength of the motor is so abnormally reduced. In the construction of the Stow multi-speed motors, however, the design of the pole piece and plunger is such that, as the volume of effective magnetism is diminished by the outward movement of the plunger, the remaining magnetic flux is forced more and more in the direction of the pole tips, thus furnishing a magnetic fringe at all times of sufficient intensity to insure sparkless commutation.

It should be understood that while the motor carries its full load sparklessly, at any imaginable speed within its range at practically maximum efficiency, it will also carry any lesser load with a consumption of power corresponding with the actual work done. As the speed regulation is effected solely by varying the reluctance of the magnetic circuits, no controller, or rheostat, or resistance of any kind is used in the regulation of the speed, all electrical circuits and connections remaining unchanged through the entire range of speed. The machine illustrated represents a type which is being built in sizes of 5 horse-power up to 25 horse-power. For sizes above 25 horse-power automatic means can be furnished for varying the speed.

The self-regulation of the machine is as close as the regulation of motors of common form, this being due to the ample size of the armature conductors used in these machines.

It is interesting to note that in all other motors the number of operative speeds corresponds to the number of steps in the controlling device, while the motor herein described possesses a speed range of absolute continuity; in other words, between the maximum and minimum limits an infinite number of speeds may be obtained without the use of any controller or rheostat, whose parts, however well made, are liable to become burned or otherwise deranged by use.



FUSIBLE BOILER PLUGS, MADE BY THE LUNKENHEIMER COMPANY, CINCINNATI, OHIO

Improved Fusible Boiler Plugs

FUSIBLE plugs have been used in boilers for a great many years, and the United States Government, recognising the important function of this boiler accessory, requires that all plugs used on boilers of steam vessels should be made of bronze and have no other filling but pure Banca tin.

Many plugs have been offered on the market which are filled with feasible alloys composed of other metals, which, although melting at very near the same point as Banca tin, were not absolutely reliable. The United States Steamboat Inspection Service of the Treasury Department has taken cognizance of the fact that inferior plugs are offered upon

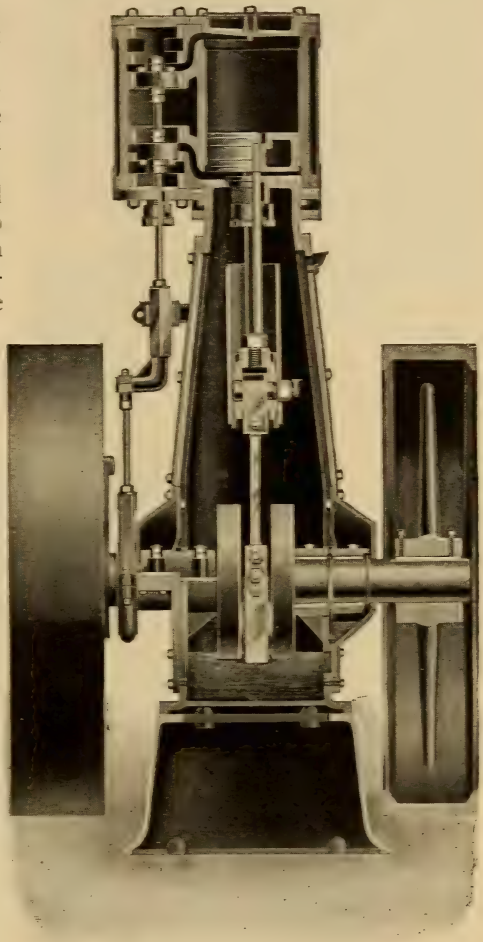
the market, and has issued a circular requiring that all fusible plugs should be filled with pure Banca tin and stamped with the manufacturer's name, and that an affidavit setting forth this fact should be filed with the inspector having charge of the boiler inspection at whatever point the plugs were used.

The Lunkenheimer Company, of Cincinnati, Ohio, have manufactured fusible plugs for a number of years, all of which comply with these specifications, and, having made affidavit before the United States Steamboat Inspection Service to the effect that their plugs comply with these requirements, these plugs are accepted by all inspectors throughout the United States.

Two forms of plugs are shown on this page, namely, the outside and inside patterns, to be screwed in either from the inside of the boiler or from the outside through the firebox or shell.

A New High-Speed Engine

A NEW high-speed vertical engine brought out by the Buffalo Forge Company, of Buffalo, N. Y., is shown on this page. The cast-iron frame, of the upright, enclosed type, formed with a graceful contour, provides for the guides within and carries above the cylinders and valve chest. The frame is mounted on a heavy cast-iron sub-base which raises the flywheel clear of the floor. The cylinders and guides are bored with the same setting of the boring bar, so that perfect alignment must result. Detachable side plates permit of ready access of the moving parts, and give an oil and dust-proof enclosure. The valve takes steam on the inside, and is of the piston type, giving a very quick opening and closing of the ports. It consists essentially of two pistons, each having its bearing surface formed by a snap ring, firmly clamped between two side plates. Either piston admits of independent adjustment. The valve is light, strong, well-balanced, and allows wear to be compensated without removal of the steam chest. The latter is fitted with iron bushings, drawn into place, bored, counter-bored, and carefully reamed. When worn through long usage, they can be readily replaced. The valve motion is obtained from a single eccentric controlled by a shaft-governor. The latter is light, strong, well-balanced, well oiled and very sensitive. It has three means of adjustment. When the engine runs under varying loads this governor will produce practically constant lead for all points of cut off. The cylinder and valve chest



A NEW HIGH-SPEED ENGINE, BUILT BY THE BUFFALO FORGE COMPANY, BUFFALO, N. Y.

are cast in one piece, to make the ports short and direct. It also reduces the clearance and radiating surface to a minimum. The cylinders and valve chest are jacketed with dead air and corrugated covering of polished sheet metal.

The cast-iron piston is light but rigid. The piston rod is of machine steel, turned to a taper, and fastened by a bolt. The crankshaft consists of a single forging of open-hearth steel, to which is fastened the counterbalancing disc. The crank-pin is of the same diameter as the shaft. The connecting rod is of forged steel, and the crank end is of the locomotive strap type, in which the box, lined with the best babbitt, may be adjusted by means of a wedge and two screws. The other end is also arranged to receive a box, and is adjusted like the crank end.

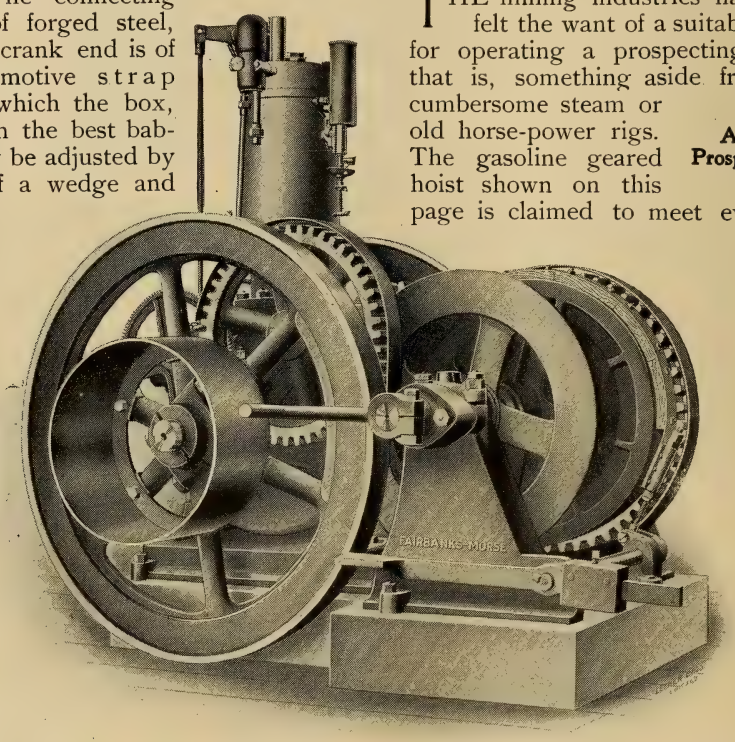
The main bearings are provided with the best babbitt metal scraped to a perfect bearing surface. They are arranged with rings which run in oil, and constantly carry it to the bearing surface. The crankshaft and connecting rod are enclosed and run in oil, so that perfect lubrication of the main bearings, crosspins, wrist-pin and guides is assured. Other bearing surfaces are provided for by constant oilers of large capacity, and the cylinders and steam chest are provided with a large sight-feed lubricator.

This engine may be equipped with extended sub-base for the direct connecting of any standard generator. Its compactness for such purposes is admirable.

A Gasoline Prospecting Hoist

THE mining industries have long felt the want of a suitable outfit for operating a prospecting shaft, that is, something aside from the cumbersome steam or old horse-power rigs. The gasoline geared hoist shown on this page is claimed to meet every requirement of this class of work. Although it is comparatively light as a whole, it has been designed to sectionalise so that the largest part does not exceed 250 pounds in weight. It can, therefore, be taken into portions of the country not readily accessible for large and heavy machinery. When set up it forms a one-piece outfit, self-contained.

The fuel for the engine is either gaso-



A GASOLINE PROSPECTING HOIST, MADE BY MESSRS. FAIRBANKS, MORSE & CO., CHICAGO

line, distillate, or crude oil, one of which can usually be purchased at a low figure in the particular locality in which the outfit would go, and as the fuel is in a liquid state, it is much more easily transported, and, if necessary, can be delivered on mule back at a much less cost than other fuels. A few gallons of gasoline, weighing but a few pounds, will, it is said, run one of these prospecting outfits for a week. The comparative cost is also claimed to be less than solid fuel.

No water is required except for the first filling of the cooling tank, as the same water is used continually. The engine is fitted with a belt pulley for the purpose of driving other machinery, such as a dynamo for operating an electric drill or a pump.

The gearing used on this combination is cut from the solid. It works with little friction and the least possible noise. The gears are so arranged that they throw out of mesh and allow the engine to be used independently when used for operating other machinery.

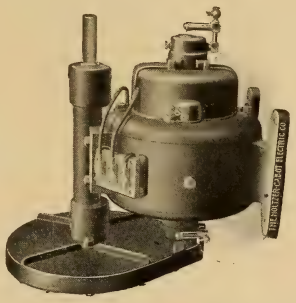
The hoist is fitted with a friction clutch on the drum, which has a wood-filled face acting on a finished iron surface. A band brake is provided, which is also wood-filled. In fact, these hoists have all the latest improvements, the same as furnished on the large outfits which Messrs. Fairbanks, Morse & Co., of Chicago, manufacture, such as their speed controller, which regulates the speed to suit the will of the operator, thus making the engine run at its minimum speed when not hoisting, and effecting a saving in the consumption of fuel.

Brazing Cast Iron

SOME interesting demonstrations as to the possibility of brazing iron have recently been made by the American Brazing Company, of Philadelphia, through the agency of a liquid flux called "Ferrofix." The object accomplished is that of brazing together broken parts of cast iron or steel. The parts to be brazed are heated in a forge to a suitable temperature; the flux is applied to the surfaces to be united, and the pieces are clamped together and allowed to cool. After the lapse of a suitable time, depending upon the size of the work, the clamps may be removed, and the result is a union, claimed to be equal in strength to the original. Cross section being equal, pieces of cast iron brazed together by this method are claimed to have shown greater strength at the joint than in the rest of the casting, this being shown by subjecting the piece to a second fracture. The process of the American Brazing Company is said to be applicable to all forms of shop work, and to possess a range from broken gear teeth to the repair of the largest and heaviest machinery.

Back-Geared Electric Motors

THE accompanying cut shows a one-horse-power back-geared motor of a line which is being manufactured by the Holtzer-Cabot Electric Company, of Boston, Mass. These motors are made in the usual sizes, from 1-6 up to 20 horse-power. They are bi-polar up to 3 horse-power, and above that multi-polar. The poles are laminations of soft steel which fit into curved seats in the field ring. The motor may be furnished in either semi-enclosed or completely enclosed form.



A BACK-GEARED ELECTRIC MOTOR, MADE BY THE HOLTZER-CABOT ELECTRIC COMPANY, BOSTON

The heavy casting which holds the gear shaft is bolted to the body of the motor and is entirely separate from the end cases, so that either the gear rigging or armature may be removed with-

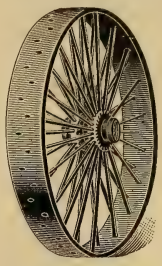
out interfering with each other. The alignment of the gear shaft is quite independent of the end cases, so that the motor may be run in any position by simply turning the end cases through a portion of a revolution in order to keep the oil rings in proper position. Self-oiling and self-aligning bearings are used.

The brush ring is held in a machine seat in the front end case, a construction which provides ample adjustment for the brushes, and, by doing away with the rocker arm, makes the commutator and brushes quite easy of access. The doors are hinged on the front bearing.

These motors show an unusually low heat loss for machines of this type. They have been found to meet the rigid requirements of the United States Navy, and are being used extensively for navy yard and ship-board work.

Steel Wheels

THE annexed cut shows a steel wheel manufactured by the Electric Wheel Company, of Quincy, Ill. This company are making steel wheels for all purposes, and are selling large quantities of them to mines and factories. The wheels are made of any size required, also of any width and thickness of tire and to fit any axle. The makers carry in stock tires from 2 inches to 16 inches wide and from ¼ to ¾ inch thick. The wheels are built to carry from 500 pounds to 6000 pounds each, and are used on anything from a hand-cart to a traction engine. They are serviceable around mines and factories and for construction work of all kinds.



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